B. L. BOGUSLAVSKY

AUTOMATIC AND SEMI-AUTOMATIC LATHES

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First Impression

PEACE PUBLISHERS
MOSCOW

TRANSLATED FROM THE RUSSIAN
BY NICHOLAS WEINSTEIN

DESIGNED BY A. BESSONOV

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ТОКАРНЫЕ АВТОМАТЫ И ПОЛУАВТОМАТЫ

НА АНГЛИЙСКОМ ЯЗЫКЕ

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Part One

INTRODUCTORY

CHAPTER I

AUTOMATIC AND SEMI-AUTOMATIC LATHES, GENERAL ASPECTS

§ 1. CONCISE REVIEW OF MACHINE TOOL DEVELOPMENT IN RUSSIA

Engineering development and invention have been held in high regard by the Russian people for many centuries. They have always done everything in their power to advance science and engineering. Many names of Russian scientists and inventors, that have enriched the treasury of human knowledge, decorate the glorious pages of Russian history.

Distinguished feats of Russian craftsmen adorn the annals of engineering history.

Russian engineering progress reached a high level of development in the eighteenth century. Many great Russian inventions in the metal-working field date from this time.

At the beginning of the eighteenth century, the lathe hand A. K. Nartov designed and built a number of new lathes for turning gun chambers, cropping ingots, cutting screws, copy-machining operations, and others. These lathes, some equipped with the first slide-rests, also invented by Nartov, were the first true lathes in the modern sense.

The talented inventor Y. Batishchev invented a number of multiple-spindle machine tools.

In addition to his fundamental discoveries in all branches of physics and chemistry, the world-famed Russian scientist M. V. Lomonosov made many inventions in various fields of industry in the middle of the eighteenth century. Lomonosov built machine tools for metal-cutting, including a spherical-turning lathe, as well as machines for glass working.

The gifted inventor Lev Sobakin designed screw-cutting and cylinder-drilling machines.

There were many born inventors among the employees of the Tula, St. Petersburg, and Ural armouries. The names and deeds of worker-inventors of this period, such as Alexei Surnin, Stepan

Tregubov, Nikita Bakharev, Pavel Zakhava and others are well known.

The fundamentals of the modern science of cutting metals and of machine tool engineering were founded by the Russian scientists, Academician A. V. Gadolin and Professor I. A. Thime, in the middle of the nineteenth century.

The foundation for a powerful machine tool industry was laid after the Great October Revolution. New plants were built, cadres of skilled workers, setup men, and engineers were trained and the production of Soviet machine tools, as well as their incessant improvement, advanced at a new pace.

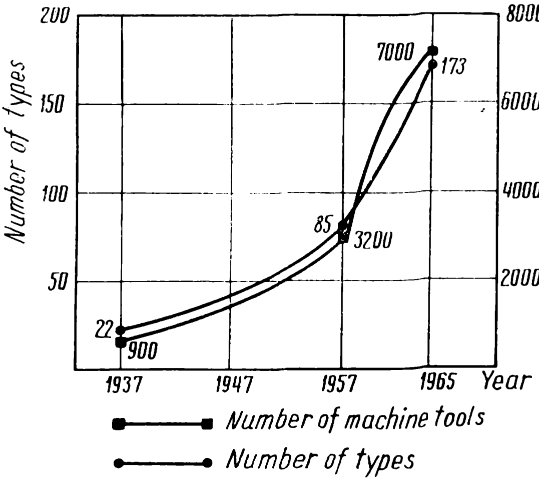


Fig. 1. Growth in the number of types and total number of automatic and semi-automatic lathes produced in the U.S.S.R.

The development of the machine tool industry in the Soviet Union may be traced on the comparative diagram of automatic and semi-automatic lathe production (Fig. 1).

About 1,500 machine tools were produced in tsarist Russia in 1913 while from 190 to 200 thousand machine tools, most of which are to be of the latest and most progressive types, including automatics, semi-automatics and multiple-spindle machines, are planned as the output for 1965 (Fig. 2).

In design, Soviet machine tools are the best in the world. They have a high production capacity and are exceptionally convenient in operation.

The Seven-Year Plan for the Development of the National Economy of the U.S.S.R. in the period from 1959 to 1965, endorsed by the 21st Extraordinary Congress of the C.P.S.U., provides for extensive development of mechanisation and automation in all branches of the national economy and for the application of automatic and semi-automatic machine tools for all types of metal-working operations.

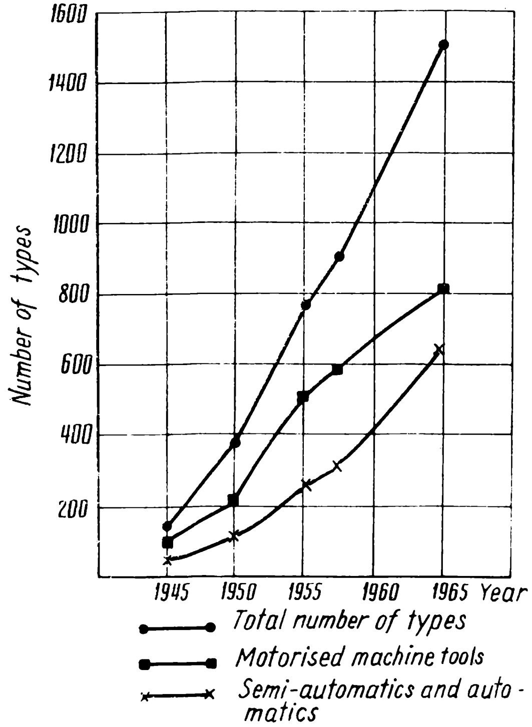


Fig. 2. Growth in the number of types of highly-automated machine tools.

§ 2. FUNDAMENTALS OF METAL-CUTTING MACHINE TOOL AUTOMATICITY

Machine tools are precise and complex machine implements which serve to produce machine parts by metal-cutting, i. e., by removing metal in the form of chips.

Semi-automatics and automatics are among the most highly productive machine tools.

The operation of an automatic machine tool and, all the more, its setting up, can be entrusted only to persons with a comprehensive knowledge of its design and principles of operation.

Automatic lathes are high-speed machines and, therefore, the observance of safety rules in their operation is obligatory for all attendants and servicing personnel.

If all servicing and handling instructions are strictly observed, the operation of an automatic lathe will present no hazard whatsoever to the workman.

All operations in machining a workpiece on a metal-cutting machine tool are classified as either *processing* or *handling operations. Processing operations* are those in which the actual cutting process or chip removal takes place. The rest are *handling operations* and include loading and clamping the work, advancing and withdrawing the cutting tools, releasing and unloading the work, checking the size of the workpiece, etc.

In up-to-date machine tools, the processing operations are performed by the operative mechanisms of the machine tool. Handling operations are performed in various ways in different machine tools. A part or even all of the handling operations are performed in certain cases by corresponding mechanisms. The operator of other types of machine tools performs the handling operations himself.

The faster the working and handling operations are performed in a machine tool, the less time will be required to produce a workpiece and the more workpieces can be produced in the same period of time by a given machine tool, i. e., the higher the productive capacity of the machine tool. If more handling operations are performed by the machine tool without the participation of the operator, he will spend less time on attending the given machine tool and can handle more machine tools at the same time. Such machine tools enable a workman to machine more workpieces per shift and, consequently, his labour will prove more productive. Machine tools, designed with mechanisms that perform the majority of the required handling operations without the direct participation of the operator, are called *automatic machine tools.*

Hand labour is reduced to a minimum in automatic machine tools and consists in setting up certain mechanisms, observing their operation and eliminating any trouble that may arise.

An increasing degree of machine tool automaticity is an important factor in raising the production level as a whole.

Developments in engineering lead to further improvements in production processes and new methods for automating machine tools are devised.

Highly automated machine tools, and especially of the lathe family, are ordinarily classified as automatics and semi-automatics.

Automatics, as their name implies, are machine tools which machine workpieces automatically. They have a fully automatic working cycle repeated to produce duplicate parts without participation of the operator. All of the working and handling operations are performed in a definite sequence by the control system adopted in the automatic, which must be set up to suit the given job. The only non-automatic operations are loading the blanks (or bar stock) for a batch of parts and inspecting the work in the course of operation. In some instances, automatic inspection is incorporated in the design of the machine tool.

Semi-automatics are machine tools in which the actual machining operations are performed automatically in the same manner as on automatics. In this case, however, the operator loads the blank into the machine, starts the machine, checks the work size, and removes the completed piece by hand. The machining cycle is automated, but direct participation of the operator is required to start each subsequent cycle, i. e., to machine each subsequent workpiece.

Machine tools, not classified as automatics or semi-automatics, may also possess a certain degree of automaticity which varies for various types of machine tools. The more automatic operations they have, the nearer they approach the design level of machine tools with a semi-automatic or a fully automatic operating cycle.

Not only highly automated machine tools are produced in the U.S.S.R. *Automatic transfer machines*, *automated production departments*, and even *fully automated plants* are being designed and built in ever-increasing numbers. Here, a large number of machine tools, arranged in the required order to process a workpiece of given design, are linked together with an automatic conveyer. The workpiece passes from unit to unit and is machined in a definite sequence of operations. Such a method is called completely or comprehensively automatic machining.

Automatic transfer machines, automated production departments and plants are the highest form of part machining automation and the production process employed in this case is said to be *comprehensively automated.*

The role of the setup man becomes more and more important in connection with the automation of machine tools and production processes. He must be able to properly set up such machines, check their operation, and remedy certain defects in their mechanisms. The skill of the setup man not only influences the quantity of work produced, but its quality as well. The setup man should have sufficient technical training and should have a most comprehensive knowledge of the design and setting-up procedure of the automated machine tools entrusted to his care.

§ 3. IN WHAT WAYS THE OPERATION OF SEMI-AUTOMATIC AND AUTOMATIC LATHES DIFFERS FROM THAT OF ENGINE AND TURRET LATHES

The difference between the machining methods, applied on machine tools which have various degrees of automaticity, may be properly understood by considering the operation of engine and turret lathes.

The blank for a spur or helical gear may be machined on either a multiple-tool semi-automatic or on a semi automatic tracer-controlled lathe (Figs 3 and 4) in accordance with the required form of the gear and its specific dimensions. If this gear is turned on an engine lathe, the following operations will be performed after setting up and clamping the blank and the cutting tools: the spindle speed and the rate of tool feed are set to the selected values, the tool is advanced to the work, carriage power feed is engaged to turn the outside diameter, the spindle is stopped, the work diameter is measured, and the tool is withdrawn from the work. These operations are repeated several times for machining the hub, faces and other surfaces of the gear.

So many manual operations are required to machine each workpiece on an engine lathe that the operator must closely attend the lathe during the whole time machining takes place. The large number of movements, he is obliged to make, tires the operator so that he cannot increase the rate of production by merely working faster.

At first, special devices were developed to automate certain of the handling operations on engine lathes to increase their production capacity. When such attachments are employed, the machining cycle of the engine lathe may approach that of a semi-automatic. If a considerable number of workpieces is required, i.e., for long-run production, it will be more expedient to do the job on a semi-

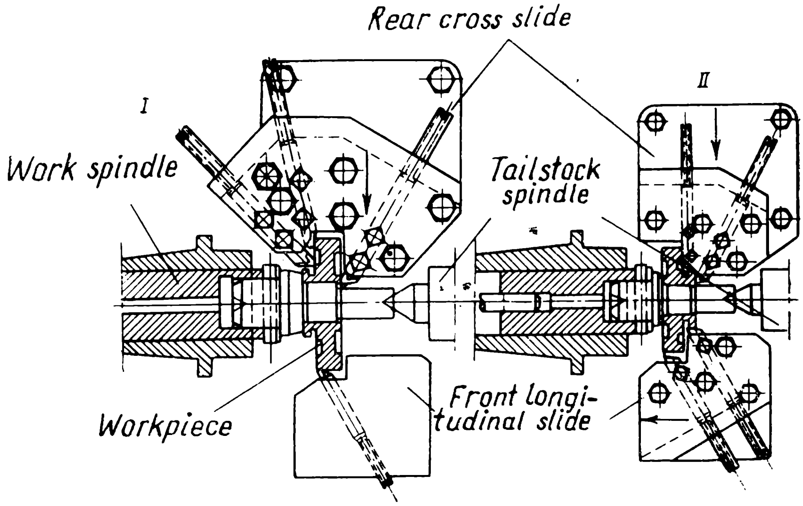


Fig. 3. Tooling setups for turning a gear blank in a multiple-tool semi-automatic lathe.

I—turning right-hand side, *II*—turning left-hand side.

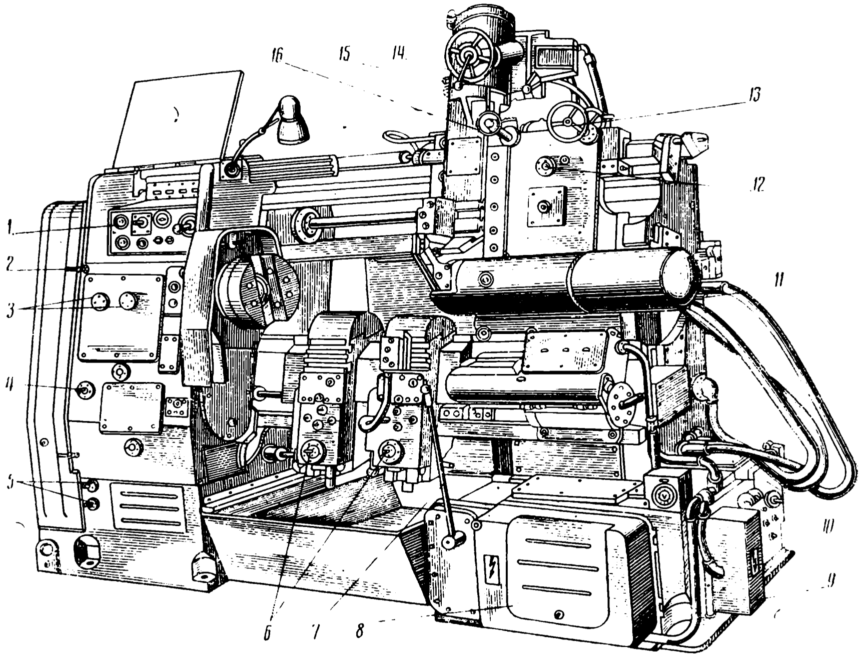


Fig. 4. Semi-automatic tracer-controlled lathe.

1—setup control panel, 2—operation control panel, 3—hexagon socket shafts for changing spindle speeds, 4—handle for cleaning the filter of the headstock lubricating system, 5—cocks for coolant feed to upper and lower slides, 6—square shanks for setting the tool to the required depth of cut, 7—tailstock spindle control lever, 8—longitudinal (tracer) slide control panel, 9—cross (facing) slide control panel, 10—tailstock spindle control panel, 11—screw for traversing the tailstock, 12—handle of the lubricator, 13—handwheel for setting the template or model in a longitudinal direction, 14—handwheel for setting the depth of cut, 15—lever for clamping the tracer carriage, and 16—handwheel for adjusting the tracer stylus stop

automatic (Fig. 5) or a fully automatic lathe (Fig. 6) which must be set up and tooled for the designed operations.

A semi-automatic or an automatic lathe is set up by setting the required spindle speed and the rates of travel of the various units carrying the cutting tools, by adjusting and clamping the tools and by determining the time required for each motion and for the complete machining cycle.

Production may begin only after the semi-automatic is properly set up. Then the operator loads and clamps the blank manually and starts the machine. All operations required to machine the workpiece will be performed automatically by the various mechanisms and when they are completed, the machine will stop automatically. The operator then removes the finished work, loads a new blank and starts the semi-automatic again. This procedure will be repeated for each workpiece.

If, however, the same gear blanks are machined on a fully automatic lathe (see Fig. 6), then not only the complete machining cycle, but all of the handling operations will be performed by the mechanisms of the machine. For this purpose a magazine-loading device (Fig. 7), holding several blanks, is mounted on the machine.

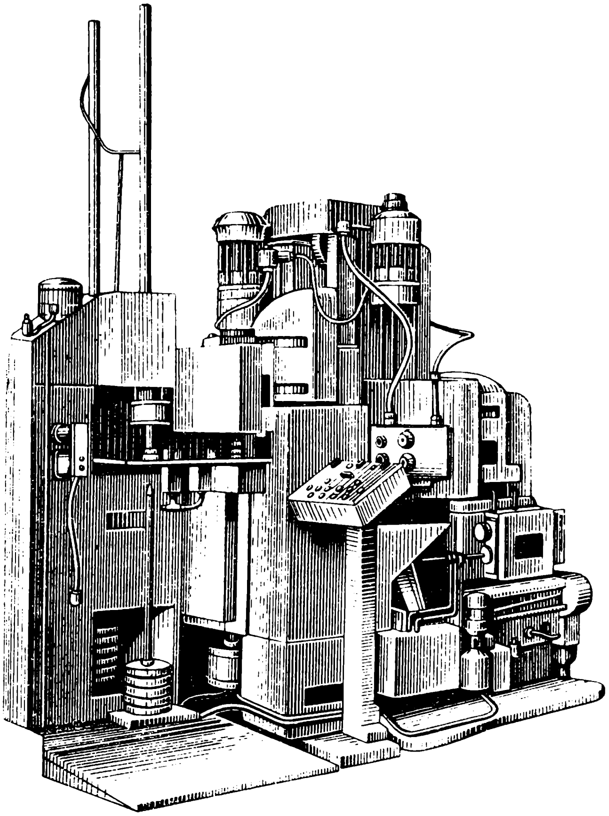


Fig. 5. Hydraulic semi-automatic vertical lathe, model 1П734.

The loading mechanism sets the blank into the working position. Here the blank is clamped and the operating units are engaged automatically to start the machining operation. After this, the toolslides return to their initial positions, and the finished workpiece is unclamped and ejected from the machine. The whole cycle consisting of these movements is performed automatically.

If a bank of such automatic lathes, arranged in a definite sequence and linked together with an automatic conveyer, is set up so that a workpiece machined in one machine will be automatically

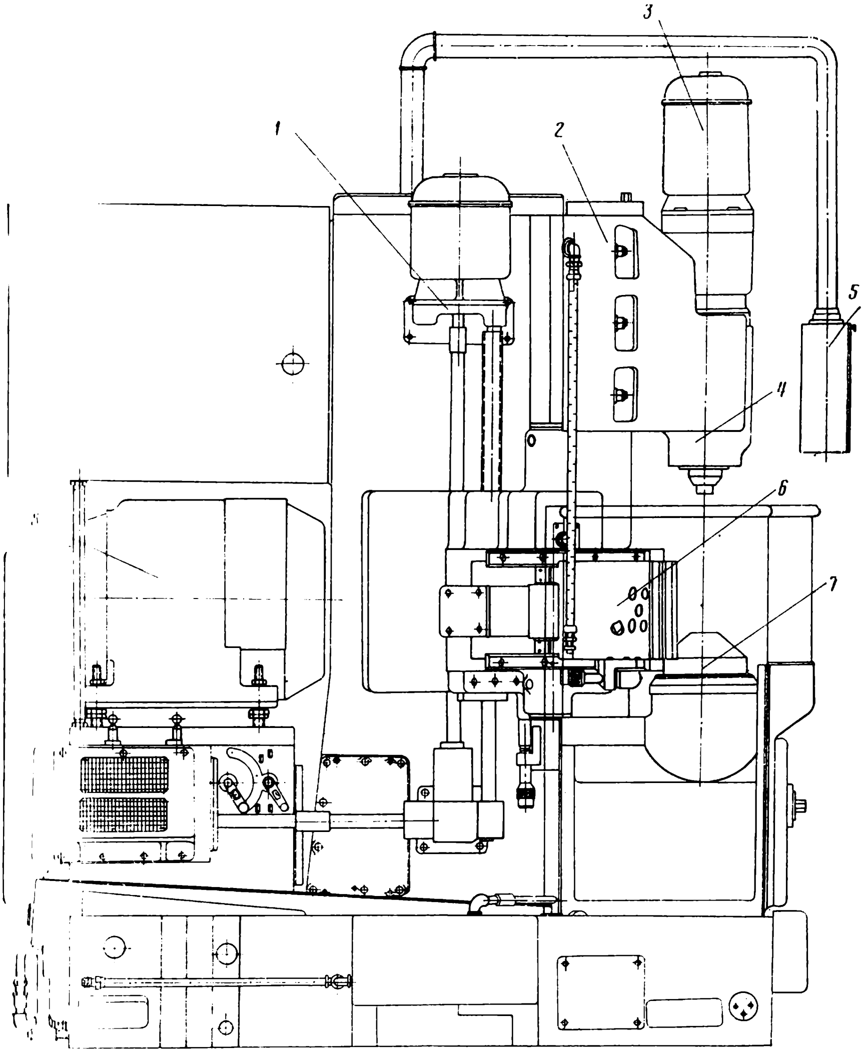


Fig. 6. Automatic vertical lathe, model 1П734.

1—electric motor, *2*—working slide, *3*—boring spindle drive motor, *4*—boring spindle, *5*—pendant push button station, *6*—lateral slides, *7*—work spindle, and *8*—main drive motor

transferred and loaded into the next machine for the subsequent operation, we will have what is called an *automatic transfer machine*.

Automatic loading devices may also be employed on universal engine lathes.

Before starting a semi-automatic or an automatic lathe on a production run, it is necessary to check the accuracy of the setup by what is called first-piece inspection. A comprehensive check-up on the first workpiece of the lot to be produced will ensure a high quality of automatic production.

If the machining methods used on engine lathes are compared with those for automatic lathes, it will be evident that very little time is lost in setting up an engine lathe but, on the other hand, a greater number of manual operations is required than for an automatic lathe.

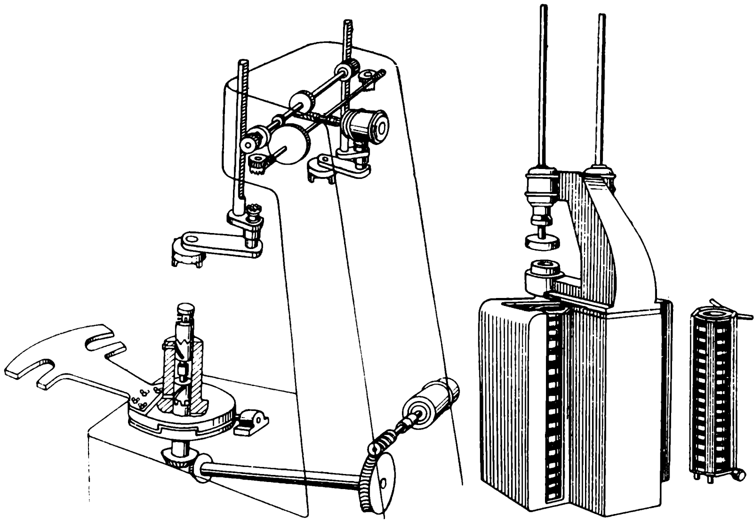


Fig. 7. Feeding and mounting gear blanks for a magazine type automatic lathe.

Therefore, if a short run is required to produce a small lot of workpieces, it will be more profitable to do the job on an engine lathe. If, however, large amounts of identical workpieces are to be machined in large-lot or mass production shops, it will prove more expedient to spend somewhat more time in setting up a semi-automatic or an automatic lathe and to obtain a substantial reduction in machining time. On an automatic lathe, the required number of workpieces will be machined in a much shorter time and with considerably less participation of the operator. As a result, the operator may attend several machines simultaneously.

A higher productivity of labour will be obtained if automatic transfer machines are employed in mass production.

The differences in operation between machine tools of the same general type, but with various degrees of automaticity, are even more apparent when an ordinary turret lathe is compared with an automatic screw machine.

Fig. 8 illustrates a tooling layout for machining a certain part on an automatic screw machine. The large number of manual movements required to machine the same workpiece on an ordinary turret lathe (Fig. 9) can well be imagined.

After setting up a manually-controlled turret lathe, the following manual operations will be required: feeding out and clamping the stock, indexing the turret to the required position, selecting and setting the proper speed and feed, advancing the turret to the work and engaging power feed, withdrawing the turret, etc.

These manual operations will be repeated at each turret position that has been utilised in the given setup. Several additional hand movements will be required during the operation of the tools clamped in the cross slide.

Since direct participation of the turret lathe operator is considerable he can attend only a single machine.

Much more time will be required to set up an automatic screw machine, but the length of the machining cycle and the direct participation of the operator will be substantially reduced. Thanks to these features, a single operator may attend several screw machines since he need only restock the machines from time to time with a new bar, make periodic measurements of the finished work, and replace dull tools.

Features that reduce the time required for changing over from one setup to another are incorporated, wherever possible, in the designs of new automatic machine tools. These features enable the machines to be expediently employed for short-run production.

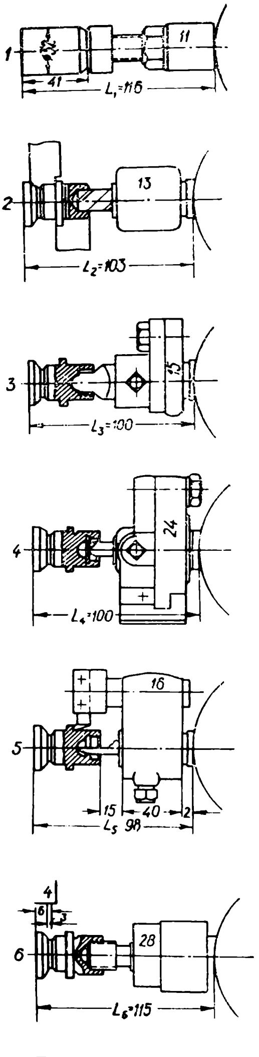


Fig. 8. Automatic screw machine tooling layout with six operation elements.

§ 4. CLASSIFICATION OF AUTOMATIC AND SEMI-AUTOMATIC LATHES AND THEIR FIELDS OF APPLICATION

Automatic lathes are mainly classified as to their size, type o· blank machined, their processing capacity (operations performed) the machining accuracy attained, principle of operation design features, number of spindles and work positions, and type Fig. 10).

In accordance with the arrangement of their spindles, semi-automatic lathes are classified as *horizontal* (see Figs. 4 and 11) and *vertical* types (see Figs. 6 and 12).

The vertical machines are heavier, more rigid and more powerful than the horizontal models and are designed for machining large-diameter work of comparatively short length. Vertical machines occupy less floor space in the shop but require higher bays than horizontal lathes.

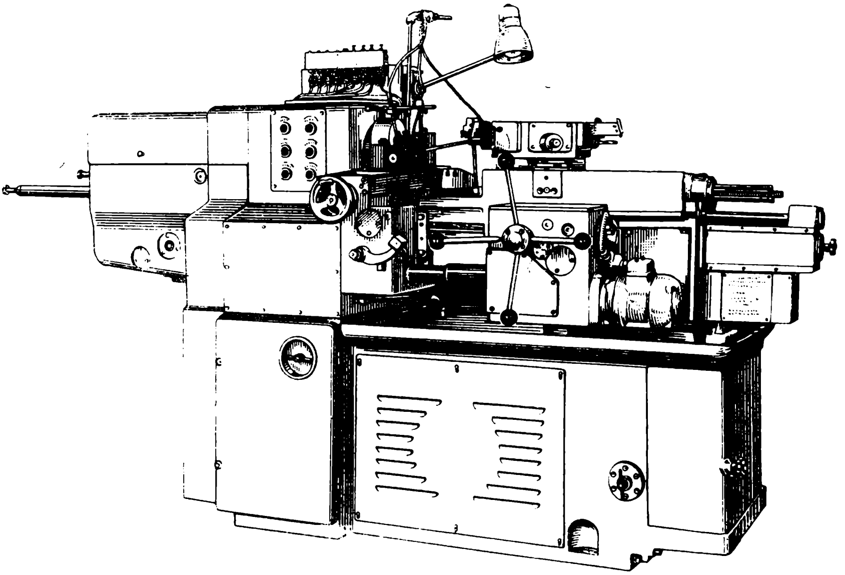


Fig. 9. Turret lathe, model 1П325.

Automatic bar machines are designed for producing workpieces of bar or pipe stock while *magazine-loaded automatics* process work from accurate separate blanks (see Fig. 7).

Semi-automatic lathes (chucking machines) are employed for machining separate blanks (hammer or die forgings, castings, or pieces of previously cut off bar or pipe stock).

Automatic lathes are chiefly used for lot and mass production.

Automatic lathes (bar machines) are employed for the manufacture of high-quality fastenings (screws, nuts, and studs), bushings, shafts, rings, rollers, handles, and other parts, usually made of bar or pipe stock and, recently, of separate blanks as well. The machining accuracy attained by these automated machines depends on the type of machine and cutting tool employed.

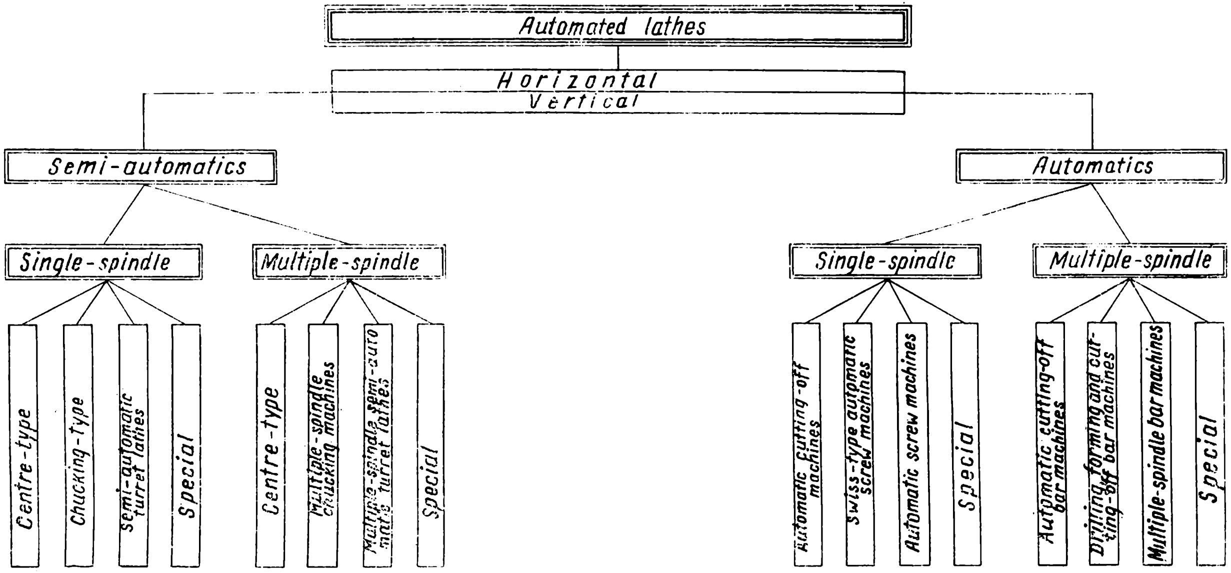

Automated lathes
Horizontal
Vertical
Semi-automatics
Automatics
Single-spindle
Multiple-spindle
Single-spindle
Multiple-spindle
Centre-type
Chucking-type
Semi-automatic turret lathes
Special
Centre-type
Multiple-spindle chucking machines
Multiple-spindle semi-automatic turret lathes
Special
Automatic cutting-off machines
Swiss-type automatic screw machines
Automatic screw machines
Special
Automatic cutting-off bar machines
Drilling, forming and cutting-off bar machines
Multiple-spindle bar machines
Special

Fig. 10. Automatic and semi-automatic lathe classification chart.

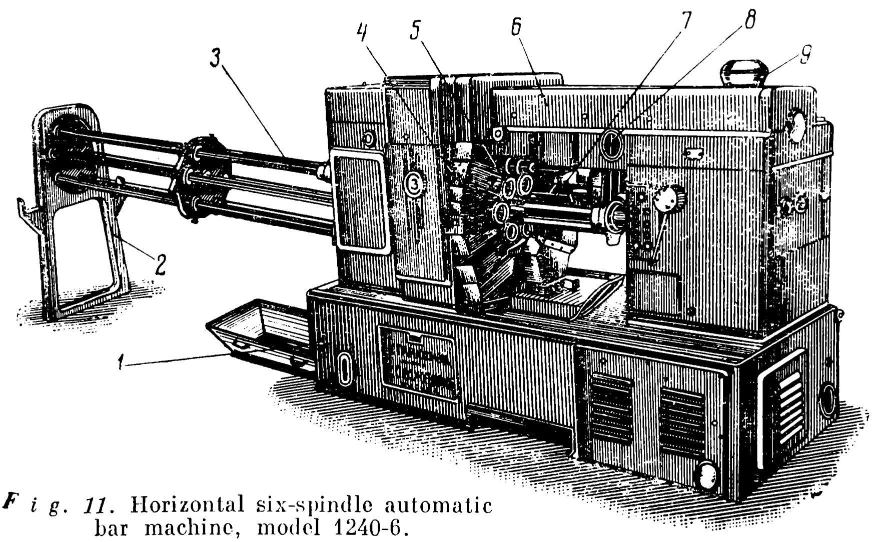


Fig. 11. Horizontal six-spindle automatic bar machine, model 1240-6.

1—chip pan, 2—stock reel stand, 3—stock tubes, 4 — side toolslides, 5 — work spindles, 6 — top brace with camshaft, 7 — end toolslide, 8 — cycle indicator, 9—drive motor for setting up operation.

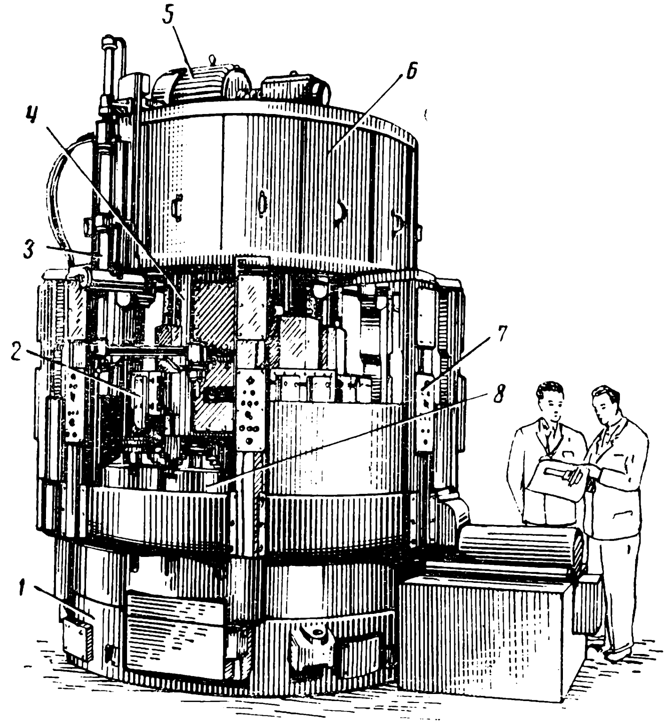


Fig. 12. Vertical eight-spindle semi-automatic chucking machine, model 1283.

1—base, 2—toolslide, 3—automatic work handling device, 4—column, 5—main drive motor, 6—top section containing speed and feed gearboxes, 7—push button station, and 8—spindles with chucks.

Automatic and semi-automatic lathes are classified as *single-spindle* (see Figs. 4 and 6) and *multiple-spindle types* (see Figs. 11 and 12).

Multiple-spindle automatics and semi-automatics may have from two to eight spindles. Their production capacity is higher than that of single-spindle machines but their machining accuracy is somewhat lower. The rate of production of a multiple-spindle machine, however, is less than that of the corresponding number of single-spindle machines. The production capacity of a four-spindle machine, for example, is only 2½ to 3 times (and not 4 times) more than that of a single-spindle machine.

Automatics and semi-automatics are chiefly designed for the performance of the following machining operations: *centering*, *turning cylindrical*, *tapered and formed surfaces*, *drilling*, *boring*, *reaming*, *spot facing*, *knurling*, *cutting threads*, *facing and cutting off*.

Special attachments for automatic lathes provide for such additional operations as *slotting (milling slots for a screw driver in screws)*, *milling flats*, *cross drilling*, *etc.*

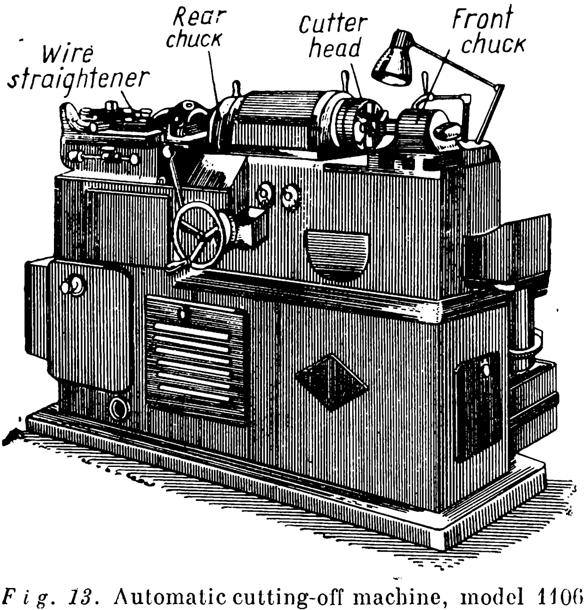


Fig. 13. Automatic cutting-off machine, model 1106 for coil feed.

Automatics and semi-automatics are also classified as machines designed for producing complex work, requiring a large number of cutting tools, and machines for simple parts.

Selection of the proper type of machine for producing a given workpiece should be made with due consideration for the type of machining operations required, the number of workpieces required, their accuracy, the required production capacity, etc.

Many types and sizes of single- and multiple-spindle automatics and semi-automatics are manufactured in the U.S.S.R. More and more of these high-production multiple-tool machines, designed and built by Soviet engineers and workmen, are being produced every year.

§ 5. PRINCIPAL TYPES OF SINGLE-SPINDLE AUTOMATICS

Single-spindle bar and magazine feed automatics are designed for various types of machining operations and are further classified as *automatic cutting-off machines*, *Swiss-type automatic screw machines*, and *automatic screw machines* (Figs. 13, 16, and 17, respectively).

Automatic cutting-off machines (Fig. 13) can produce short workpieces of simple form by means of cross-feeding tools (Fig. 14). These automatics are simple in design. The headstock with the spindle is mounted on the bed. Two cross slides are located on the bed at the front end of the spindle. Cams on a camshaft actuate the working movements of the cross slides through a system of levers.

Special one-, two-, and three-station attachments are used for machining holes and cutting thread on these machines.

Swiss-type automatic screw machines (Figs. 15 and 16) are designed for machining long accurate parts of small diameter (2 to 25 mm) (Fig. 18). An exclusive feature of these machines is the longitudinal travel of the headstock or of a quill carrying the rotating work spindle. The end of the bar, projecting from the chuck, passes through a guide bushing (steady-rest) beyond which the cross-feeding toolslides are arranged. A wide variety of formed surfaces may be obtained on the workpiece by coordinated alternating or simultaneous travel of the headstock (longitudinal feed) and the cross slides (approach to the depth of cut). Holes and thread are machined by attachments similar to those used on automatic cutting-off machines.

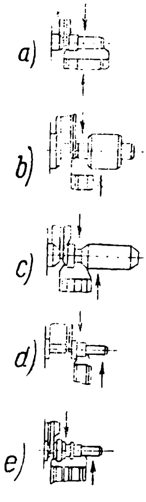


Fig. 14. Tooling setups for various work on single-spindle automatic cutting-off machine.

Single-spindle automatic screw machines (Fig. 17) are essentially wholly automatic bar-type turret lathes. They are designed for machining complex external and internal surfaces on parts made of bar stock (see Fig. 8) or of separate blanks (Fig. 19). Up to ten different cutting tools may be employed at one time in the tooling of such a screw machine. The tools are clamped in the holes at the

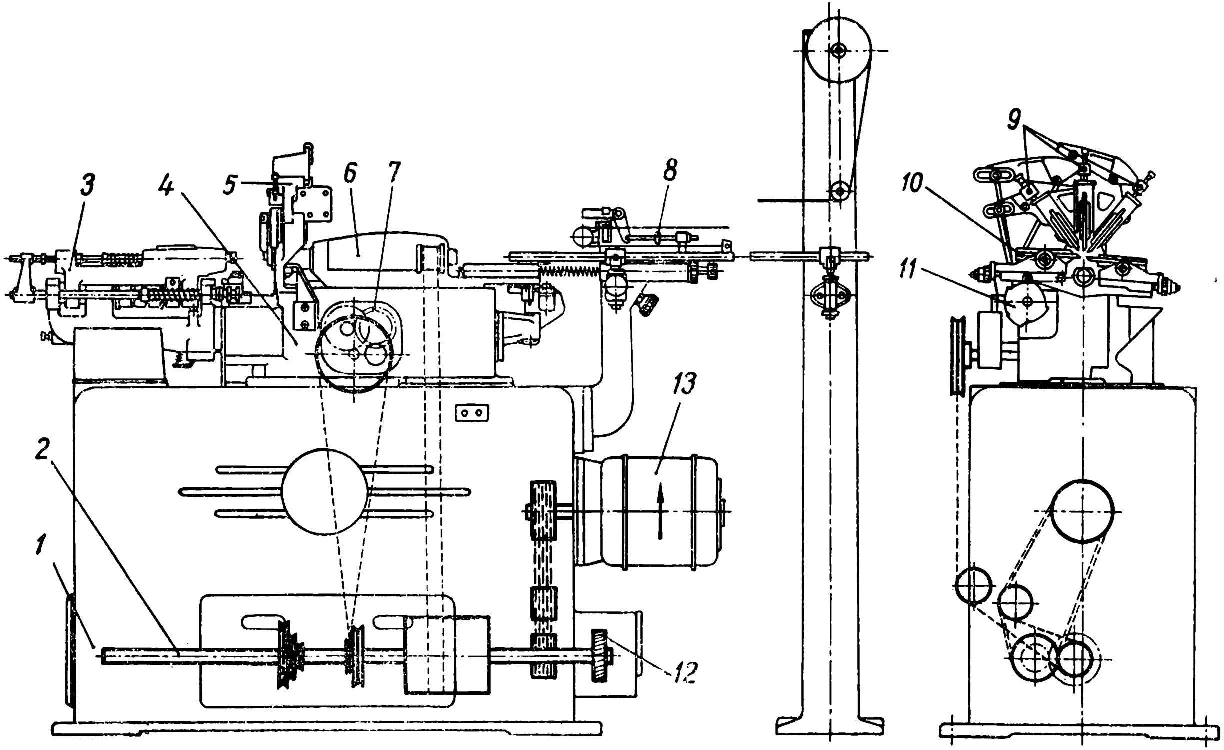


Fig. 15. Swiss-type automatic screw machine.

1—base, *2*—driving shaft, *3*—tool device, *4*—bed, *5*—cross-feeding toolslide support, *6*—headstock, *7*—camshaft drive change-gears, *8*—stock feed, *9*—cross-feeding toolslides, *10*—rocker-arm toolslide, *11*—cam, *12*—change-gears, and *13*—main drive motor.

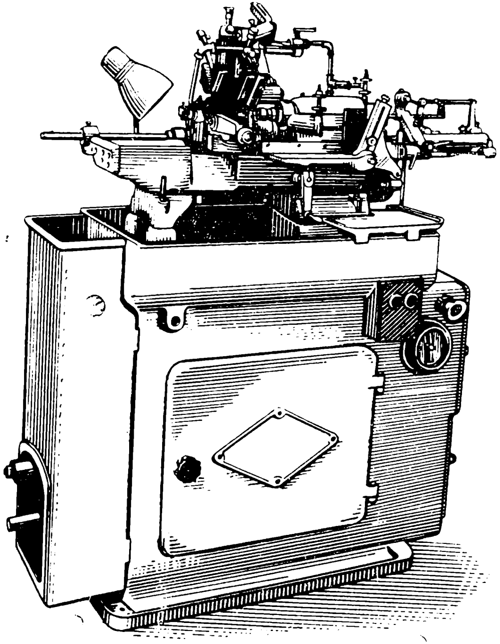


Fig. 16. Swiss-type automatic screw machine, general view.

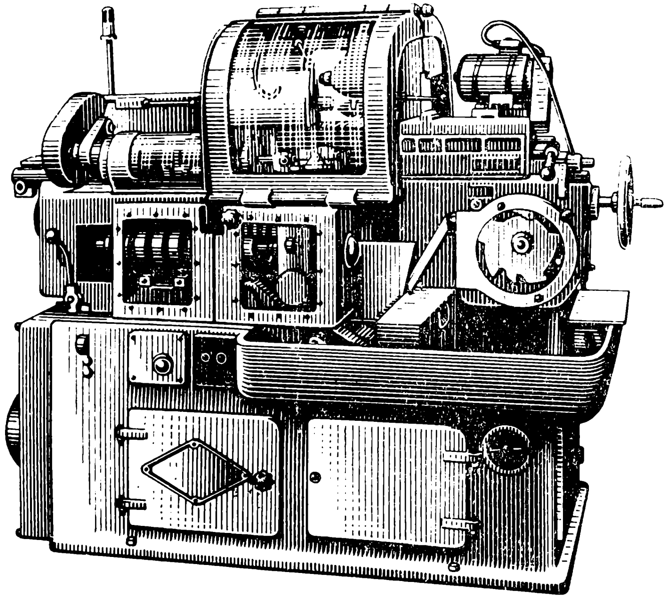


Fig. 17. Automatic screw machine, model 1140.

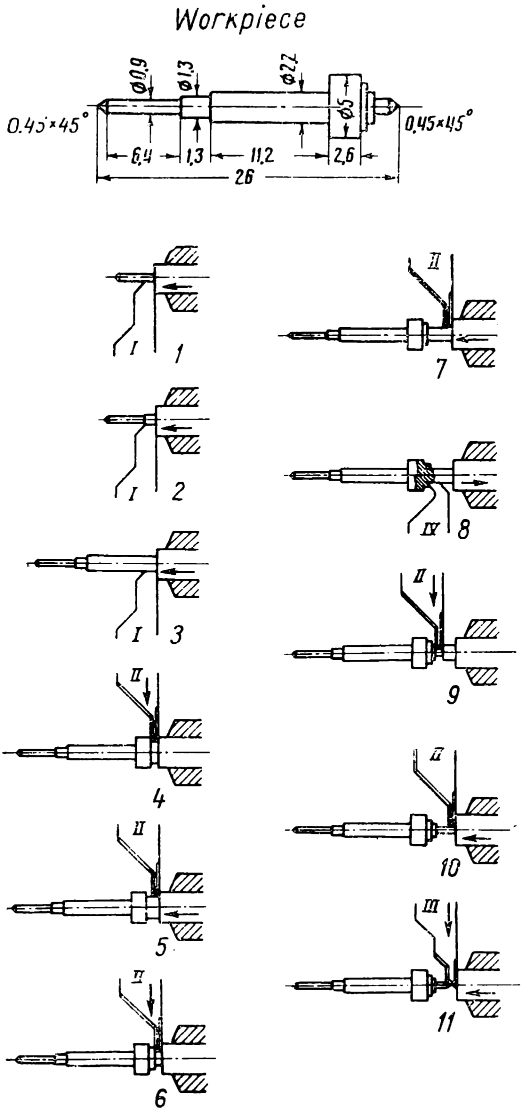


Fig. 18. Tooling layout for Swiss-type automatic screw machine.

I and *II*—operation elements, *I-IV*—tools.

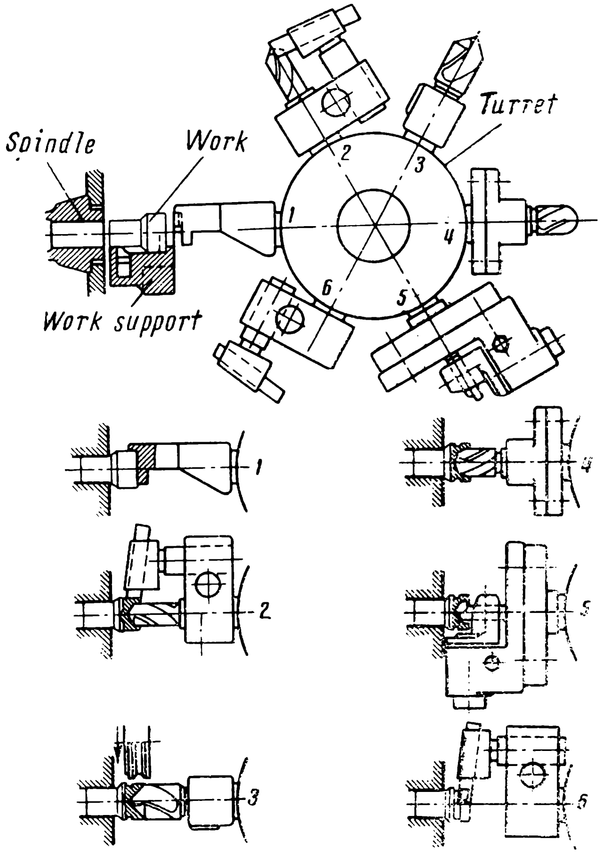


Fig. 19. Tooling layout for machining separate blanks on an automatic screw machine.

1 to *6*—turret stations or positions.

positions of the periodically indexing turret and in the cross slides. The stationary headstock, mounted on the left end of the bed, houses the spindle which rotates in either direction. The turret slide is arranged at the right end of the bed and carries the turret having six tool holes. Two cross slides (front and rear) are provided for cross-feeding tools. A vertical slide attachment which provides an additional (third) cross slide may be employed. It is installed above the work spindle. All movements of the machine units are actuated by cams mounted on the camshaft.

§ 6. PRINCIPAL TYPES OF MULTIPLE-SPINDLE AUTOMATICS

In accordance with the type of blank used, multiple-spindle automatics are also classified as either bar-type or magazine-loading machines.

In their principle of operation, they may be classified as *parallel-* and *progressive-action* automatics.

Multiple-spindle *parallel-action* automatics are often called *multiple-flow* machine tools. The same operation is performed on each spindle and a workpiece is finished in each spindle in one working cycle. This means that as many workpieces are simultaneously machined as there are spindles. Such machines have a very high rate of production but may be applied for very simple work only since the whole machining process takes place at one position (station) (Fig. 20 *a*).

Multiple-spindle parallel-action automatics are usually automatic cutting-off bar-type machines and are used to produce the same work as single-spindle automatic cutting-off machines. Centering or a single drilling operation may also be performed on certain models. In design, these machines comprise a frame with a headstock at the right end. The headstock houses the horizontal work spindles which are arranged in a line, one above the other. All working and auxiliary motions of the machine units are obtained from the cams mounted on the camshaft. Cross slides (side toolslides) are located at the right- and left-hand sides of the spindles and carry the cross-feeding tools. Each side toolslide accommodates tools for all of the spindles.

In *multiple-spindle progressive-action automatics (multiple-station machines)*, the blanks, clamped in each spindle, are machined progressively in station after station (Fig. 20 *b* and *c*).

As a rule, these machines (see Fig. 11) have a headstock mounted at the left end of the base. It contains the spindle carrier. A column at the right end is a gearbox. Independent side toolslides are provided on both sides of the spindle carrier. The end toolslide, which accommodates tooling for all of the spindles, travels on the spindle carrier stem. A top brace, connecting the headstock and gearbox on

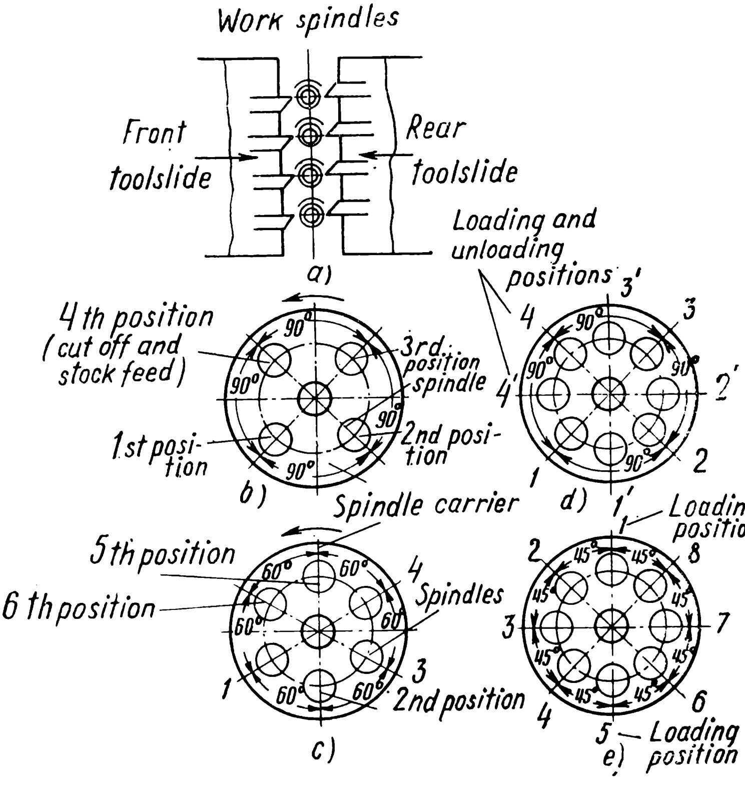


Fig. 20. Types of multiple-spindle operation.
a — parallel-action (multiple-flow), *b* and *c* — progressive-action (multiple station), *d* and *e*—parallel-progressive action.

top, imparts the required rigidity to the frame. The camshaft with the cams is located in this top brace.

The spindles of these machines are mounted in a carrier which periodically indexes through a definite angle. In a four-spindle machine of this type, each blank indexes through four stations in which it is machined; in a six-spindle automatic the blank indexes through six stations, etc. It is evident that much more complex workpieces may be produced on multiple-spindle progressive-action automatics than on the parallel-action models. In each cycle of a progressive-action machine, machining is finished in one spindle, i. e., one part is produced. In one revolution of the carrier, as many workpieces are produced as there are spindles in the carrier.

In certain six-spindle automatics of this type, stock is fed out at two stations, for example, *2* and *5*. One workpiece will be machined consecutively at stations *1*, *3*, and *5* and the other at stations *2*, *4*, and *6*. Consequently, two workpieces will be finished at each cycle or indexing. Each piece will pass through only one-half of the stations on the automatic. This is called double-indexing or the *parallel-progressive* principle and enables the rate of production to be sharply increased for simple workpieces.

In this manner, multiple-spindle automatics and semi-automatics may operate so as to produce two workpieces instead of one at each indexing. In these cases, stock is fed or the blank is loaded and the finished workpiece is unloaded at two stations which are arranged either adjacently (Fig. 20 *d*) or on opposite sides of the carrier (Fig. 20 *e*).

§ 7. PRINCIPAL TYPES OF SINGLE-SPINDLE SEMI-AUTOMATICS

Semi-automatic lathes are employed for machining work from separate blanks. The operator unloads the finished work, loads and clamps the blank and starts the machine. Time required for handling operations may be substantially reduced by a proper selection of the clamping devices.

Single-spindle semi-automatics are classified as *centre* and *chucking types*. In the first, the work is held between centres (Fig. 21 *a* and *b*) and in the second, in a chuck (Fig. 21 *c*, *d* and *e*). External stepped or formed surfaces are usually machined on centre-type semi-automatics. A headstock and a tailstock are mounted on the bed of such a machine. The work is machined by two groups of cutting tools. The front toolslide holds the cutting tools which require a longitudinal feeding motion (to turn the steps of a shaft) while the rear toolslide holds tools that require a transverse feed motion (to perform facing, shouldering, necking, chamfering, and similar operations).

Single-spindle chucking semi-automatics may be equipped with various toolslide arrangements. If internal surfaces are to be machined in addition to external surfaces, semi-automatics having a central end-working toolslide or a turret are employed. These machines are usually equipped with longitudinal and transverse feed toolslides as well.

The multiple tooling principle, in which machining is performed with several cutting tools simultaneously, is often applied on single-spindle semi-automatics (Fig. 21 *a* and *e*). The *tracer-control principle*, employing a single tool, is also widely used. Finally, a combination method is applied in which the straight turning is performed by a single tracer-controlled tool and cross feeding operations, by several tools (Fig. 21 *b* and *d*).

Single-spindle semi-automatic lathes are either of horizontal (see Fig. 4) and more seldom of vertical design. The feed motions may be obtained either mechanically (from a camshaft with cams) or from a hydroelectrical system.

Single-spindle semi-automatics may be converted into fully automatic machines by the provision of a magazine and automatic loading and unloading devices (see Fig. 7).

A large number of types and sizes of single-spindle semi-automatic lathes are manufactured in the Soviet Union. These include special, single-purpose machines designed for turning crankshafts, camshafts and other complex work.

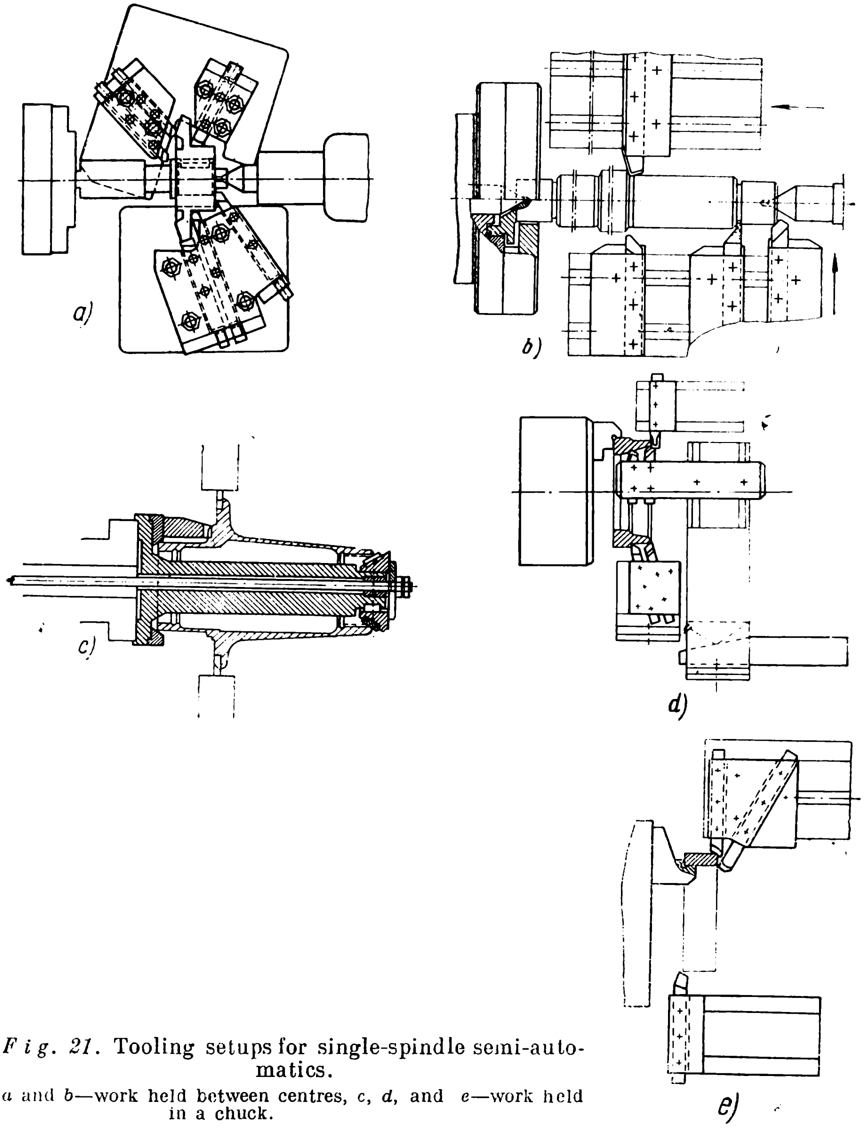


Fig. 21. Tooling setups for single-spindle semi-automatics.

a and *b*—work held between centres, *c*, *d*, and *e*—work held in a chuck.

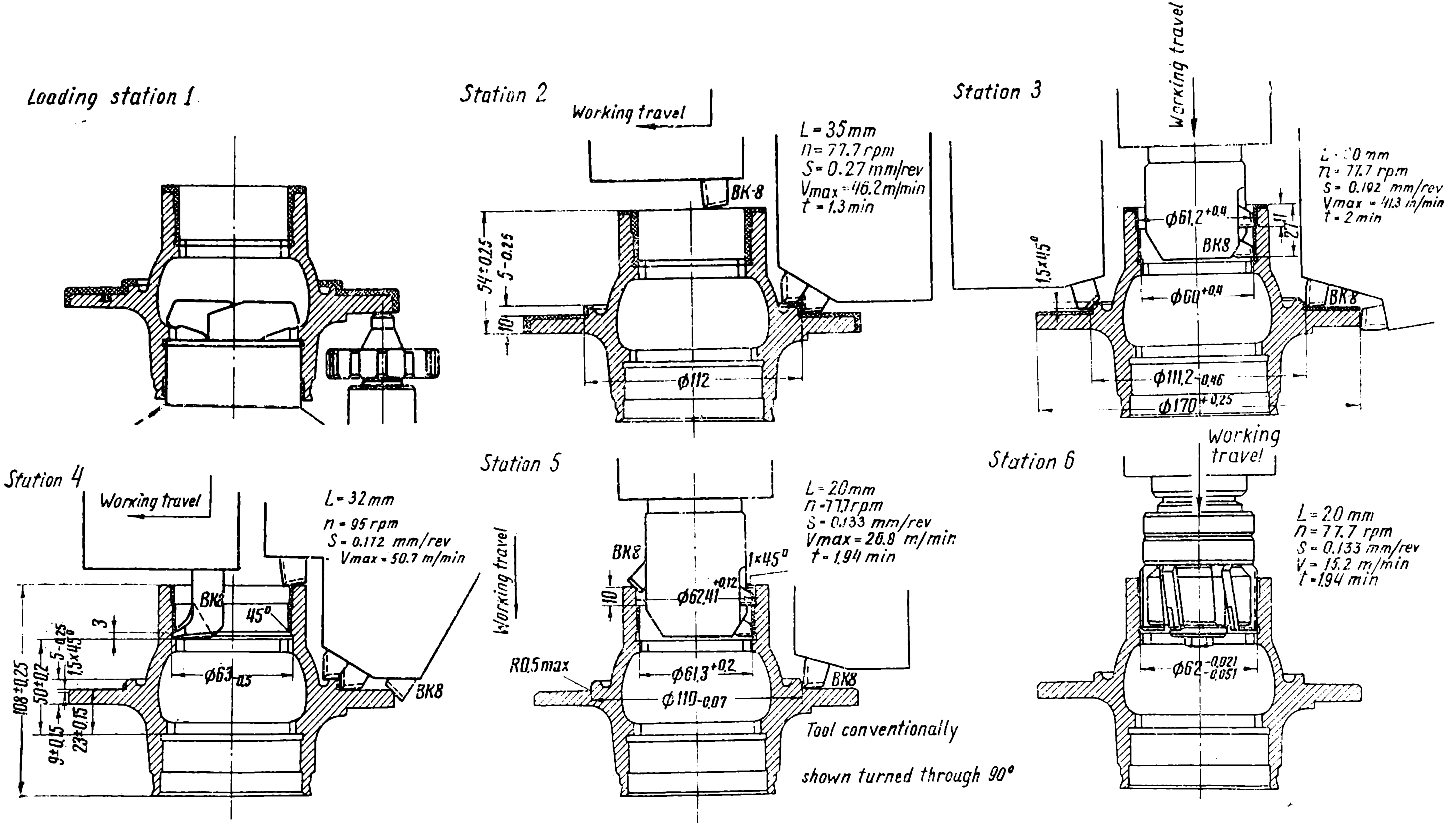


Fig. 22. Tooling layout for machining a hub on a six-spindle progressive-action vertical semi-automatic lathe.

§ 8. PRINCIPAL TYPES OF MULTIPLE-SPINDLE SEMI-AUTOMATICS

Multiple-spindle semi-automatic lathes are high-production machine tools designed for turning work between centres or clamped in a chuck. These semi-automatics, in the same way as automatics, are classified as *parallel-action (single station) and progressive-action (multiple station) types.* In the progressive-action semi-automatic, the blank clamped in each spindle is consecutively machined in each station (see Fig. 20 *b* and *c* and Fig. 22) or, in case of double-indexing, in one-half of all the stations (see Fig. 20 *d* and *e* and Fig. 23).

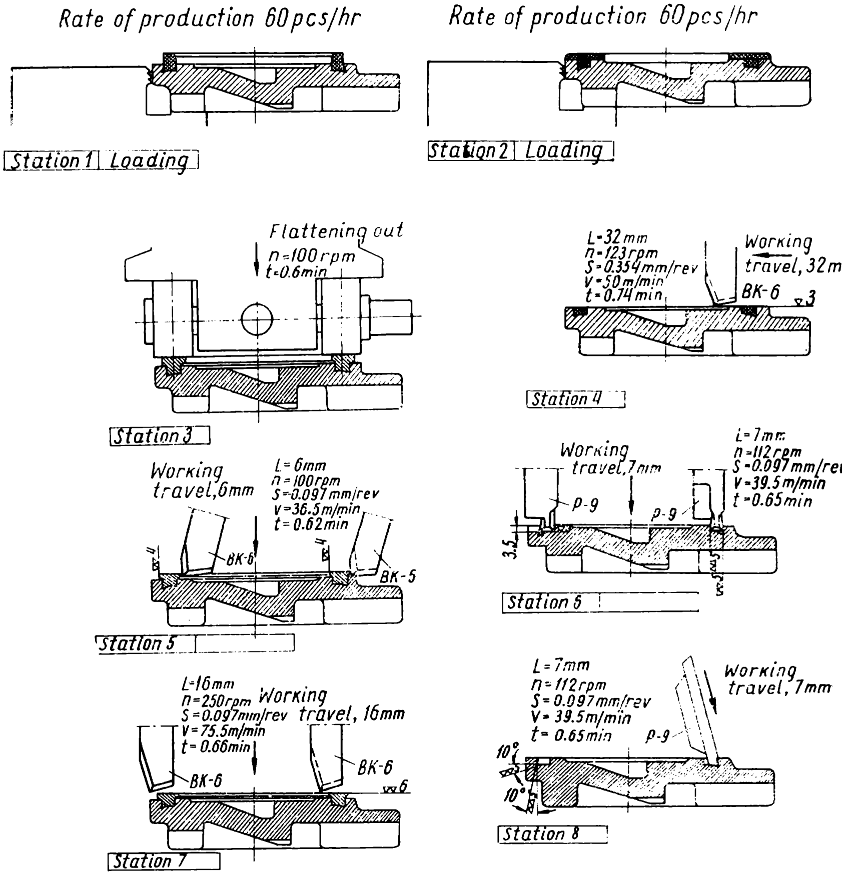


Fig. 23. Performing two different operations on a disc in an eight-spindle semi-automatic lathe with double-indexing of the spindle carrier (parallel-progressive principle).

First operation—stations *2*, *4*, *6*, and *8*; second operation—stations *1*, *3*, *5*, and *7*.

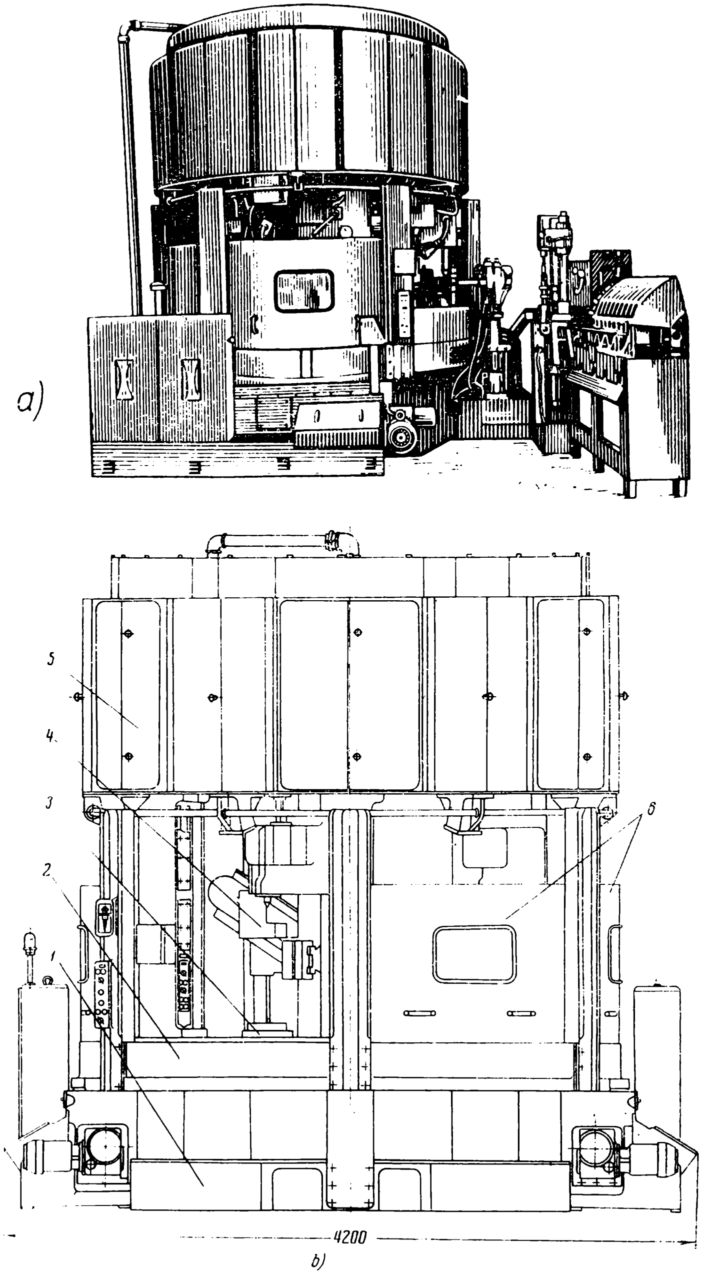


Fig. 24. Eight-spindle rotary-type vertical automatic, model 1272.

a — general view, *b* — principal units: *1* — base, *2* — carrier and outer column, *3* — spindle, *4* — hydraulic tracer-controlled slide, *5* — upper part of outer column, *6* — working zone shields.

Parallel-action semi-automatics and automatics are usually of the rotary type (Fig. 24). They operate on the principle illustrated in Fig. 25. Each spindle has its own toolslide with tools; the spindles and toolslides are mounted in a carrier and on an outer column which rotate slowly but continuously about the inner column. The workpiece in each spindle is machined during this continuous rotation of the carrier and is finished just before the carrier makes a full revolution. In this manner, when each spindle approaches the loading zone, it is automatically stopped, the finished workpiece is unloaded and a new blank is loaded. This principle of operation enables the operator to stand in one place, the loading position, during operation.

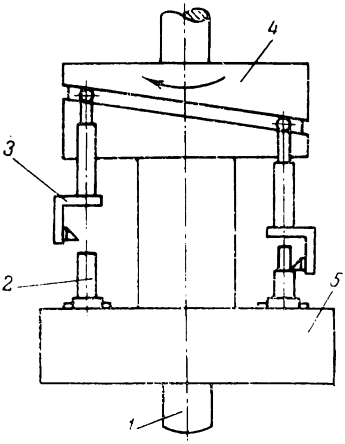


Fig. 25. Machining princip͏e employed in multiple-spinde rotary-type semi-automatics.
1 — inner column, 2 — spindle, 3 — toolslide, 4 — stationary cam slots, 5 — rotating carrier.

The operation of a rotary multiple-spindle semi-automatic can be more easily understood if it is considered as several lathes mounted on a continuously rotating column. Each lathe is loaded and started when it reaches the zone where the operator stands. This particular lathe will return to the operator's workplace after the carrier makes one revolution. During this time, the work will be machined and the lathe will be automatically stopped. This will enable the operator to remove the finished workpiece, to load a new blank and to start the lathe again. The same is true for each lathe mounted on the column.

Progressive-action semi-automatics may be converted into automatics by the provision of a magazine and automatic loading device. Difficulties are encountered in complete automation of multiple-spindle rotary semi-automatics since loading and unloading is to be done during continuous rotation of the carrier. This difficulty has been overcome in model 1272 (Fig. 24) in which the carrier indexes periodically (instead of continuous rotation) and consequently is stationary during loading.

§ 9. MACHINE TOOL HANDLING AND MAINTENANCE

Metal-cutting machine tools are complex machines which require careful handling and maintenance. Automatics and semi-automatics should never be operated by persons not acquainted with their design and principles of operation. A strict conformance to all operating rules is of prime importance. For this reason, one of the main duties of the setup man is to regularly instruct the automatic lathe operators on machine maintenance and lubrication, trouble-shooting and other aspects of machine attendance.

The setup man must teach the operators time- and labour-saving working methods and proper workplace arrangement. He should explain and demonstrate the use of cutting and measuring tools.

Automatics and semi-automatics are high-speed machines and, consequently, it is *obligatory for all attendants and servicing hands to obey all safety rules concerning their operation.*

Safety rules will be taken up in more detail in a special section concerning the design of various machines. It is nevertheless advisable for each setup man to remember the following:

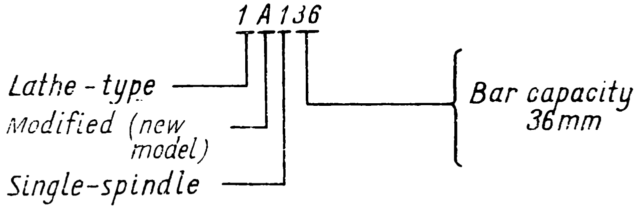
1) Before starting the machine, check whether all guards and safety devices are in place and see that overalls and working jackets are neatly buttoned or tied so that loose ends cannot be caught up by the spindles, chucks, work, or other rapidly rotating or travelling units of the machine.

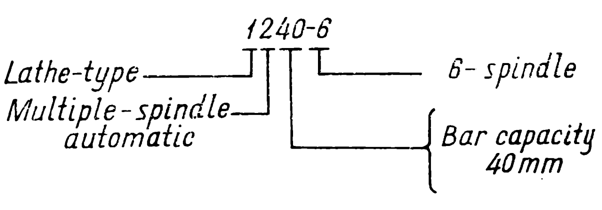
2) Never wipe off or clean the machine during operation in places near to rapidly moving parts of the machine or its drive, never repair or even touch operating mechanisms until the machine has completely stopped and there is no danger of it accidentally starting again.

§ 10. MACHINE TOOL MODEL DESIGNATION

The designation of machine tool models in the Soviet Union is based on the following principle. Each model should be designated in such a manner that it can be easily distinguished from any other type, size or model.

Examples of automatic lathe designations are given below:





Each model is assigned a definite three-or four-integer number: the first figure indicates the group of machine tools, the second indicates the type of machine while the third and fourth figures indicate the size (not necessarily directly). To distinguish a new model from an earlier model of the same type and size, letters are introduced between the figures. If several alternate design modifications are made by the manufacturing plant, another letter is added at the end of the number.

The first figure is "1" for machine tools of the lathe type. The second figure is also "1" for single-spindle automatics and semi-automatics and is "2" for multiple-spindle models.

CHAPTER II

DRIVES AND OTHER TYPICAL MECHANISMS

§ 11. CLASSIFICATION OF MOTIONS IN MACHINE TOOLS

Machine tools (this term is used throughout the book) are understood to be "metal-cutting machine tools". They consist of mechanisms designed to provide certain definite motions. The following motions are characteristic of machine tools: 1) *main cutting motion*, 2) *feed motion*, and 3) *auxiliary motions*.

Main Cutting Motion. The main cutting motion is rotary for automatic and semi-automatic lathes and is transmitted to a spindle which holds the work or, in some cases, a cutting tool. Sometimes, for example, in cutting thread with a tap or die, both the work-piece and tool may rotate simultaneously.

The cutting speed is determined from the formula

$$v=\frac{\pi d n_s}{1,000}=\frac{3.14 d n_s}{1,000} \text{ m per min} \qquad (1)$$

in which d denotes the machining diameter, in mm;

n_s denotes the spindle speed, in rpm.

This formula enables one to determine the cutting speed if the work or cutting tool of a given diameter is rotated at a selected speed.

If the machining diameter d and the required cutting speed v are given, the same equation will enable the corresponding spindle speed to be determined. For this purpose, the preceding formula is converted to

$$n_s=\frac{1,000v}{3.14d} \text{ rpm}. \qquad (2)$$

Cutting speed charts of the rectilinear type are often used to quickly determine the spindle speed for a given cutting speed. In the chart of Fig. 26, the diameters (d) to be machined, expressed in mm, are arranged on the axis of abscissae. The cutting speed (v), in m per min, is arranged on the axis of ordinates. Each slanting line or "ray" represents a definite speed step, in rpm, of the spindle of the given machine tool. To determine the required spindle speed (rpm) for a given cutting speed, we find the intersection of a vertical line drawn from the corresponding diameter and a horizontal line drawn from the required cutting speed. The speed step (ray) which coincides with this point of intersection or the nearest lower spindle speed is usually taken as the required value.

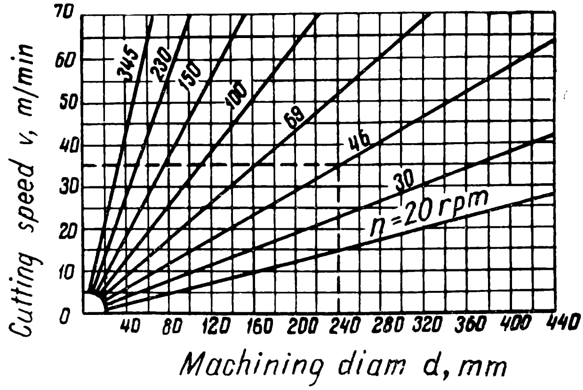


Fig. 26. Rectilinear cutting speed chart for determining spindle speeds.

Example: What spindle speed is required to machine a workpiece, 240 mm in diameter, at a cutting speed of 35 m per min (see Fig. 26)?

A vertical line is drawn from the diameter $d = 240$ mm and a horizontal line from the cutting speed $v = 35$ m per min. These two lines intersect on the speed step $n_s = 46$ rpm.

A logarithmic chart of the type shown in Fig. 27 is often used instead of the rectilinear chart to determine spindle speeds. It is used in a similar manner.

The higher the cutting speed that can be applied for a given operation, the more workpieces may be produced per hour, i. e., the larger the rate of production.

The cutting speed depends chiefly on the material to be machined, on the material of the cutting tools, the depth of cut and the rate of feed.

The application of cutting speeds, higher than the recommended values, will decrease the life of the cutting tools which will be subject to premature wear or failure.

The feed motion (s) in lathes is the movement of the cutting tool in reference to the work. This motion may be rectilinear or curvilinear; it may be in a longitudinal direction (s_l) or in a cross direction (s_c). The larger the rate of feed, the thicker the chip cut by the tool. For automatics and semi-automatics the feed is usually expressed in millimetres per revolution of the workpiece. Turning, for example, with a feed of 1 mm per spindle revolution means that the carriage with the tool travels 1 mm in a direction parallel with the workpiece axis during the time that the workpiece makes one revolution. If thread has a pitch of 5 mm, then the tool cutting the thread will travel 5 mm for each revolution of the screw being cut.

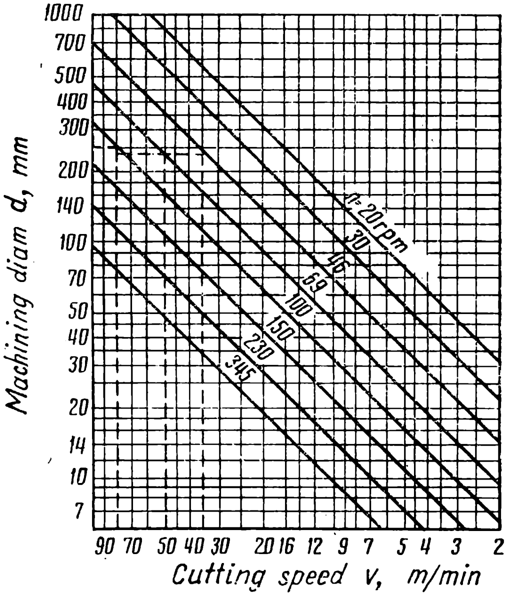


Fig. 27. Logarithmic cutting speed chart for determining spindle speeds.

The rate of feed expressed in mm per revolution is one of the factors of the chip cross-section which is the product of the depth of cut t and the feed s.

The rate of feed is selected to suit the machining allowance, provided for the given operation, and the required accuracy and surface finish. *Other conditions being equal, the rate of production will increase in direct proportion to an increase in the rate of feed.*

This may be illustrated by an example in which a shaft, 50 mm in length *(l)*, is to be turned on a semi-automatic at a feed of $s_1 = 0.1$ mm per spindle revolution. The number of spindle revolutions required to turn the shaft will equal $n_{s_1} = \frac{l}{s_1} = \frac{50}{0.1} = 500$ revolutions.

If we use a feed of $s_2 = 1$ mm per spindle revolution then the number of spindle revolutions required will be $n_{s_2} = \frac{l}{s_2} = 50$ revolutions.

In the second case, the work was turned in one-tenth of the time *at the same cutting speed.*

Therefore, to decrease the machining time, it is desirable to increase both v and s within feasible limits.

In automatic lathes with a hydraulic drive, the rate of feed is expressed in millimetres per minute (mm per min). The feed per minute s_m should be determined from the feed per spindle revolution by the following formula:

$$s_m = s \times n_s \text{ mm per min.} \tag{3}$$

Example: What will the rate of feed per minute be if the workpiece and spindle rotate at a speed of $n_s = 200$ rpm and the feed $s = 0.2$ mm per revolution? $s_m = s \times n_s = 0.2 \times 200 = 40$ mm per min.

Auxiliary motions (operations) prepare the machine, workpiece and tool for carrying out the cutting process and check whether the movements have been properly made. Auxiliary motions include loading and clamping the blank, removing the finished work, clamping and swivelling units on which the work or tools are mounted, rapid approach or withdrawal of units carrying the cutting tools, measuring the workpiece and other operations. Auxiliary movements should be performed as fast as possible to cut the time required for their performance and, consequently, to increase the rate of production of machines and operators. It is desirable that auxiliary movements coincide in time with each other or with cutting operations to further increase the rate of production.

§ 12. PRINCIPAL UNITS

The operating cycle of automatic lathes, including both working and auxiliary motions, is obtained by means of a drive and definite units and mechanisms. Though there are many different types of automatics, their drives, units and mechanisms have much in common. This enables the most widely used of these units to be generalised and typical units, drives and other mechanisms to be selected for study to facilitate a more detailed further acquaintance with the various designs of automatics and semi-automatics.

In addition to the drive, the principal units of single-spindle automatics and semi-automatics are the bed, headstock, stock feeding and chucking mechanisms, feed drive, cycle control units, toolslides, turret, tailstock, lubricating and coolant systems (see Fig. 4).

The principal units of multiple-spindle horizontal automatic and semi-automatic lathes are the frame, right column with gearbox, headstock with spindle carrier, stock feeding and chucking mechanisms, feed drive, cycle control units, end and side toolslides, auxiliary attachments, lubricating and coolant systems (see Fig. 12).

The principal units of vertical semi-automatics are the base, column, spindle carrier, clamping devices, feed drive, cycle control units, toolslides, auxiliary attachments, lubricating and coolant systems (see Figs. 6 and 12).

§ 13. DRIVES AND POWER TRANSMISSION

The workpiece and spindle rotate at a definite preset speed for any turning operation.

A feed motion must be imparted to slides and attachment spindles, carrying the cutting tools, to obtain the cutting action.

All power travel, for both working and handling movements, is obtained from the machine drive.

A definite amount of work (energy) must be expended to impart the required working and handling movements, i. e., a definite amount of power is consumed.

Just what do we mean by work and power?

Mechanical work is the product of a force *(P)* by the distance *(S)* through which it acts in the direction of the force. The force is measured in kilogrammes (kg) and the distance in metres. Therefore the work A is measured in kilogramme-metres

$$A = PS \text{ kg-m.} \tag{4}$$

The unit of power is an amount of work equal to 75 kg-m accomplished in one second. The power (N) may be expressed in either horse power (hp) or in kilowatts (kw)

$$\text{one horse power} = 75 \frac{\text{kilogramme-metres}}{\text{second}}$$

$$\text{one kilowatt} = 1.37 \text{ hp and } 1 \text{ hp} = 0{,}736 \text{ kw.}$$

To rotate a shaft, spindle or other part (Fig. 28), it is necessary to apply a force Q to a gear or pulley mounted on the shaft. This force acts on the lever arm l which equals the radius r of the gear or pulley. The product of the force Q in kg by the lever arm l in m is called the *torque*:

$$M = Ql = Qr \text{ kg-m.} \tag{5}$$

Therefore, the torque is expressed in kilogramme-metres.

The following equations are used to determine the power N which must be applied to rotate the shaft at a given speed n if it is loaded by the torque M:

$$N = \frac{Mn}{716.2} \text{ hp} \tag{6}$$

or

$$N = \frac{Mn}{975} \text{ kw.} \tag{7}$$

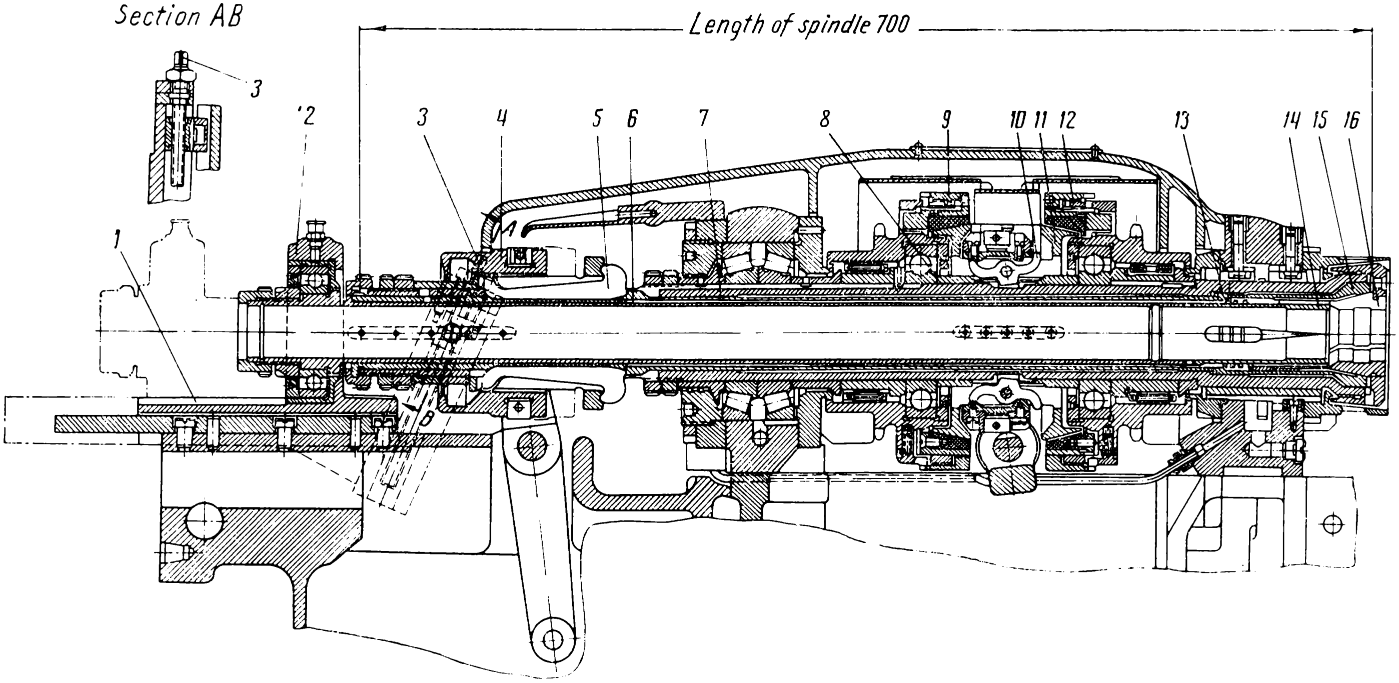


Fig. 28. Longitudinal section through headstock and spindle of the automatic screw machine, model 1136.

1 — guides of stock feed device, *2* — support of stock feed tube *6*, *3* — stock feed adjusting screw, *4* — sliding sleeve of chucking levers *5* which actuate collet tube *7*, *8* — sleeve of friction clutch, *11*, engaged to member *9* or *12* by means of clutch levers *10*, *13* — spring for rapidly unclamping the stock, *14* — feeding finger, *15*—sleeve with taper bore, *16* — spring collet.

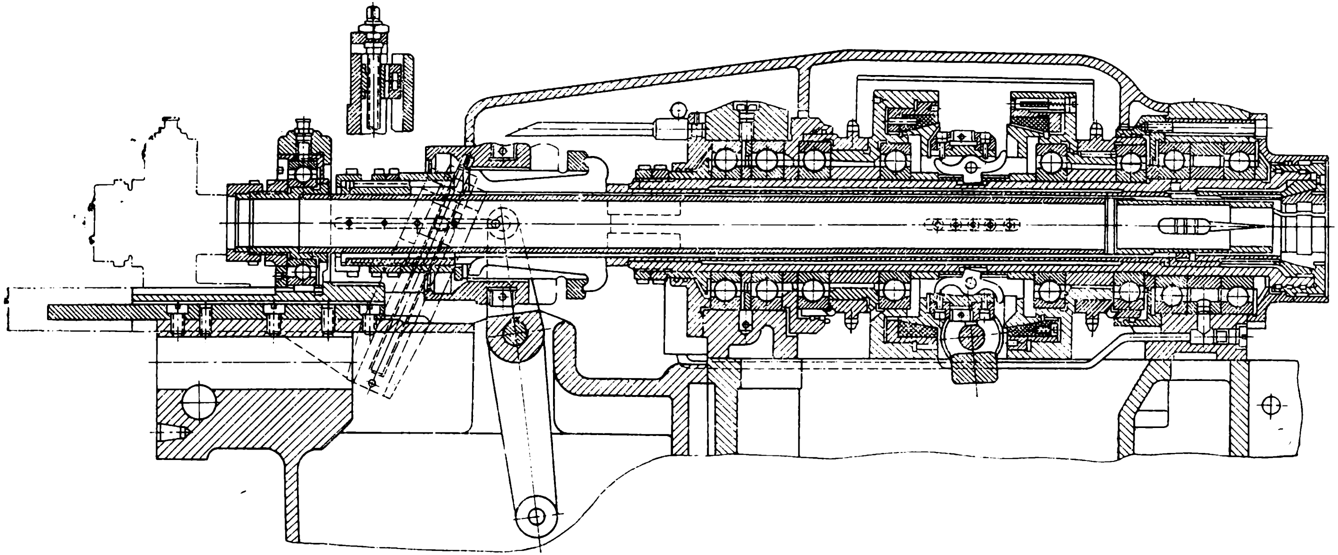


Fig. 29. Automatic screw machine spindle mounted in antifriction bearings.

The drive of a machine tool consists of a source of energy (electric motor) and devices for transmitting power from the motor to the operative elements (spindles, slides, etc.). In machine tools motion and power are transmitted from the drive motor to the various units through belts, chains and toothed gearing which are called *transmissions*. They transmit rotation from one shaft to another or convert rotary motion into reciprocating motion. Shafts run in bearings which may be either plain bearings (Fig. 28) or antifriction bearings (Fig. 29). Special requirements are made to the spindle, its drive and bearings since their precise and proper adjustment will affect the operation and even the production capacity of the machine. Shafts and spindles are more frequently mounted in antifriction bearings since their friction losses are less than in plain bearings.

The friction surfaces in bearings must be lubricated to provide for quiet and reliable operation of spindles, shafts and transmissions.

The chief elements of transmissions are pulleys with belts, sprockets with chains, toothed gearing, screws and nuts and others.

Hydraulic drives, whose elements will be described in detail in Chapter III, are widely employed in the latest models of automatic lathes.

§ 14. BELT DRIVES

Round, flat, and V-belts are used in machine tool drives. The directions of rotation of the pulleys mounted on the driving and driven shafts *coincide for open belts* (Fig. 30 *a* and *b*) *and are opposite for crossed belts* (Fig. 30 *c*). The speed of the shaft, on which the smaller pulley is rigidly mounted, is higher than that of the shaft on which the larger pulley is rigidly mounted. To increase the speed of the driven shaft, rotation should be transmitted from a pulley of

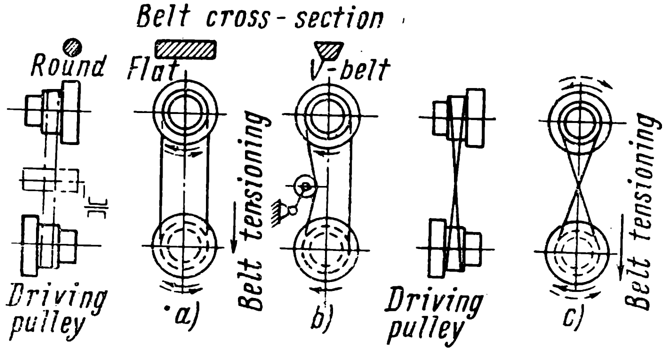


Fig. 30. Belt drives.
a and *b*—open belts, *c*—crossed belt.

larger diameter to one of a smaller diameter. On the contrary, if the speed of the driven shaft is to be decreased, its pulley should be of a larger diameter than that of the driving pulley.

The speed of the driven shaft n_{dn} is determined from the formula

$$n_{dn}=\frac{D_{dr}}{D_{dn}}\times n_{dr}\ \text{rpm} \tag{8}$$

in which n_{dr} denotes the speed of the driving shaft in rpm.

D_{dn} and D_{dr} denote the diameters of the driven and driving pulleys, respectively, in mm.

The ratio $\frac{D_{dr}}{D_{dn}}$ is called the *transmission ratio* and is denoted by the letter i, therefore:

$$\frac{D_{dr}}{D_{dn}}=i \text{ and } n_{dn}=in_{dr}\ \text{rpm.} \tag{9}$$

§ 15. CHAIN DRIVES

Roller chain (Fig. 31*a*) and silent chain (Fig. 31*b*) are employed in machine tool drives. The directions of the driving and driven sprockets coincide as in open belt drives. To determine the speed of the driven shaft n_{dn}, the speed of the driving shaft n_{dr} is multiplied by the ratio of the number of teeth on the driving sprocket Z_{dr} to the number of teeth on the driven sprocket Z_{dn}:

$$n_{dn}=\frac{Z_{dr}}{Z_{dn}}\,n_{dr}\ \text{rpm.} \tag{10}$$

The ratio $\frac{Z_{dr}}{Z_{dn}}=i$ is called the *transmission ratio of the chain drive* and therefore:

$$n_{dn}=in_{dr}\ \text{rpm.} \tag{11}$$

§ 16. TOOTHED GEARING

Toothed gearing (Fig. 32) serves for transmitting motion between *parallel*, *intersecting*, and *crossed* shafts. Spur, parallel helical or herringbone gears are used to transmit rotation between parallel shafts (Fig. 32 *a*, *b* and *c*). Straight or spiral bevel gears are used between intersecting shafts (Fig. 32 *e*). For crossed shafts, worm gearing is used (Fig. 32 *f*) or crossed helical gears.

Rotary motion is converted into reciprocating motion or vice versa by means of a pinion and rack (Fig. 32*g*) or by other mechanisms which will be described further on.

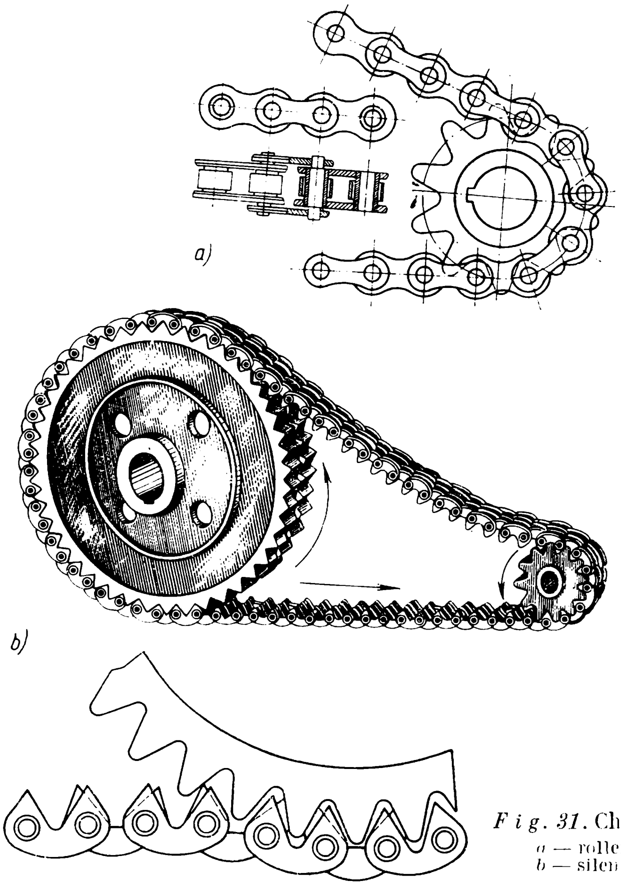


Fig. 31. Chain drives
a — roller chain,
b — silent chain.

The same formulas as for chain drives are used for determining the speed of a driven gear:

$$n_{dn}=\frac{Z_{dr}}{Z_{dn}}\ n_{dr}\ \text{rpm.}; \qquad (12)$$

$$\frac{Z_{dr}}{Z_{dn}}=i;$$

$$n_{dn}=in_{dr}\ \text{rpm.} \qquad (13)$$

The ratio $\frac{Z_{dr}}{Z_{dn}}=i$ is called the *gearing ratio.*

In external spur and helical gearing, the driving and driven shafts rotate in opposite directions (Fig. 33 *a*).

If two shafts are to rotate in the same direction, then an intermediate or idler gear (Fig. 33 *b*) is arranged between the gears on the

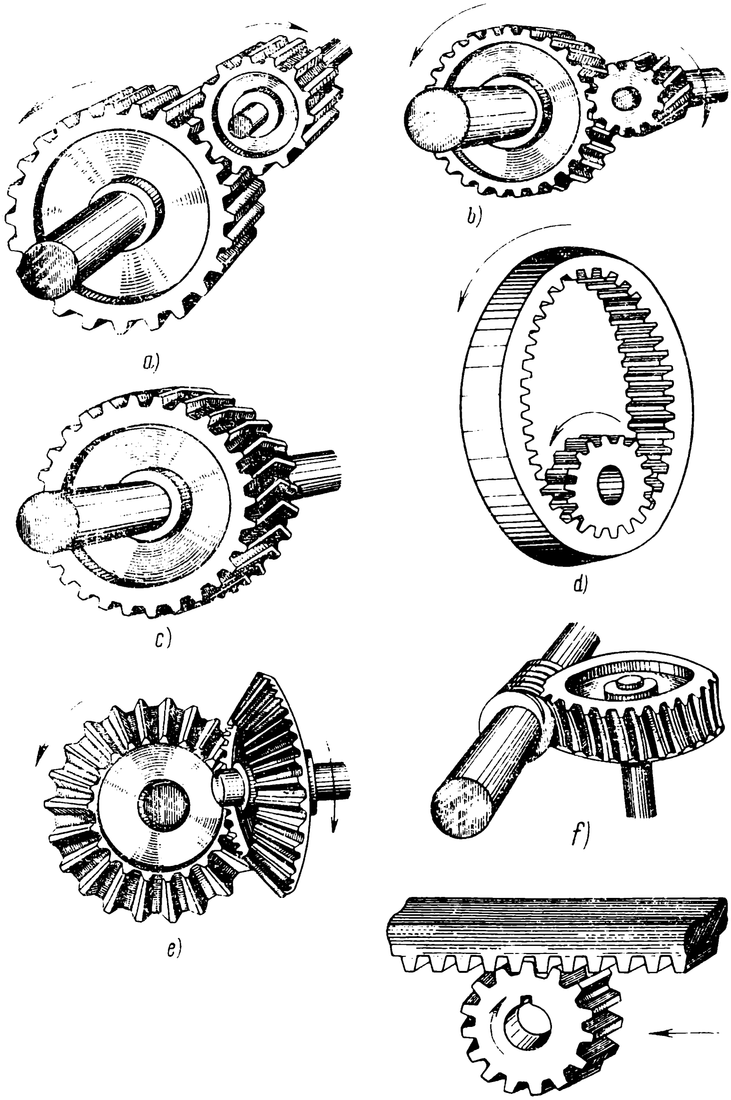


Fig. 32. Toothed gearing.

a — spur gears, *b* — parallel helical gears, *c* — herringbone gear, *d* — external and internal gears, *e* — straight bevel gears, *f* — worm and wheel, *g* — rack and pinion.

shafts or external and internal, spur or helical gears are used (Fig. 32 *d*).

The direction of rotation of bevel gears depends on their location. In Fig. 33 *c*, two bevel gears are mounted freely on the shaft. They mesh with a large bevel gear; the left-hand gear rotates in one direction and the right-hand gear, in the opposite direction. This feature is used to impart rotation alternately in either direction to a shaft by engaging the clutch to the corresponding gear.

Trains of gears are employed in gear boxes (Fig. 33 *d*). The speed of the last or fourth shaft (n_{IV}) of the gear box (Fig. 33 *d*) may be determined after determining the speeds of all the intermediate shafts, according to formulas (12) and (13):

$$n_{II}=\frac{Z_1}{Z_2}n_I \text{ rpm}; \qquad n_{II}=i_I n_I \text{ rpm},$$

in which

$$i_I=\frac{Z_1}{Z_2};$$

$$n_{III}=\frac{Z_3}{Z_4}n_{II} \text{ rpm}; \quad n_{III}=i_{II}n_{II} \text{ rpm},$$

in which

$$i_{II}=\frac{Z_3}{Z_4};$$

$$n_{IV}=\frac{Z_5}{Z_6}n_{III} \text{ rpm}; \quad n_{IV}=i_{III} \; n_{III} \text{ rpm},$$

in which

$$i_{III}=\frac{Z_5}{Z_6}.$$

To avoid such lengthy computations, the speeds of the intermediate shafts are introduced into the formula for calculating the speed of the last shaft:

$$n_{IV}=\frac{Z_1}{Z_2}\times\frac{Z_3}{Z_4}\times\frac{Z_5}{Z_6}\times n_I \text{ rpm}.$$

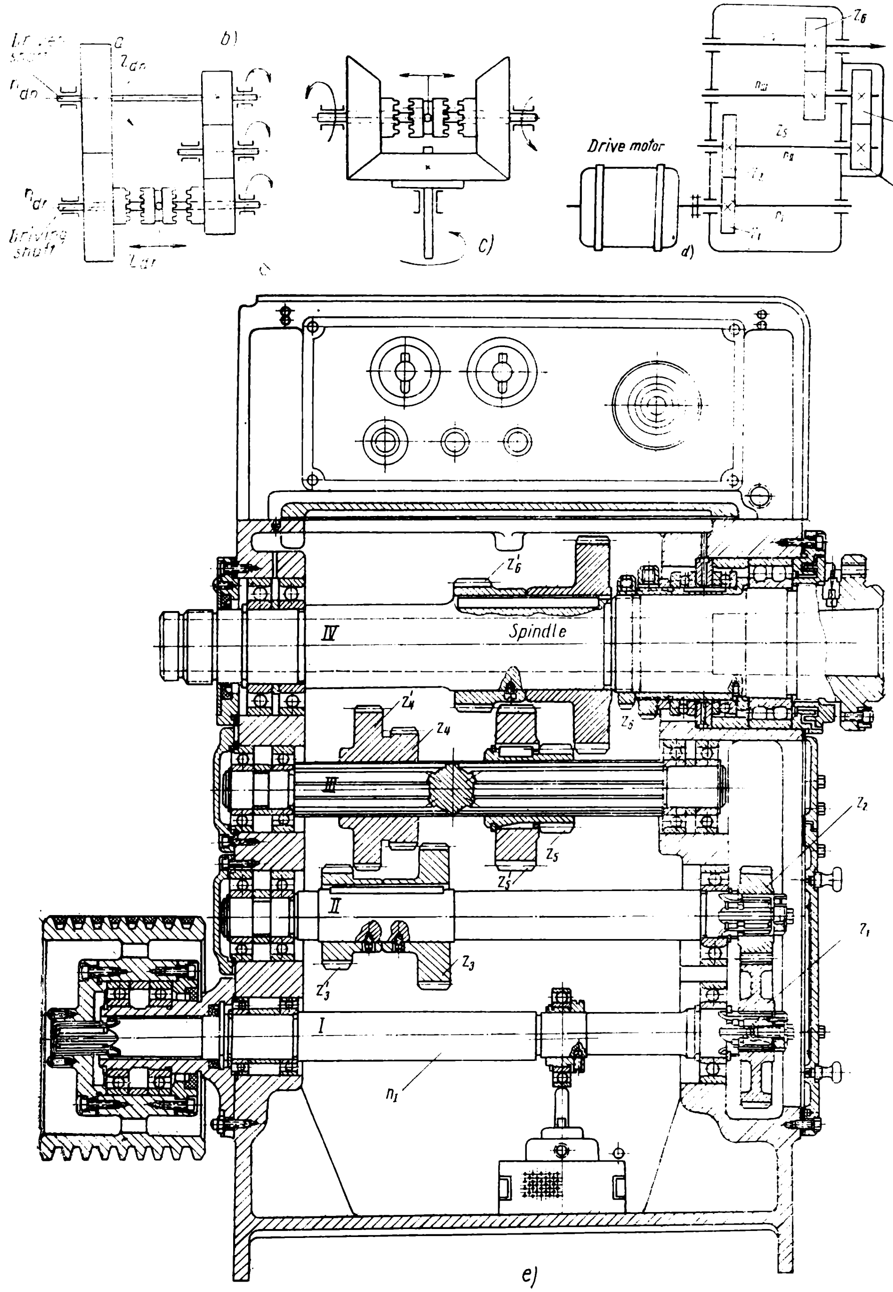
$$n_{IV}=i_I\times i_{II}\times i_{III}\times n_I \text{ rpm}.$$

Worm gearing is usually employed to sharply reduce the speed of the driven shaft on which the worm wheel is mounted since the gearing ratio *i* is very small. The direction of rotation of the worm wheel depends on the direction of rotation and the hand of the worm. The speed of the driven shatf is determined from the formula:

$$n_{dn}=\frac{a}{Z}\times n_{dr} \text{ rpm}, \tag{14}$$

$$\frac{a}{Z}=i \tag{15}$$

in which *a* denotes the number of threads or starts on the worm.
Z denotes the number of teeth on the worm wheel.



F i g. 33. Systems of toothed gearing.

a—spur or helical gearing, *b*—spur or helical gearing with intermediate gear, *c*—bevel gearing (reversing device), *d*—speed gearbox diagram, *e*—section of speed gearbox.

§ 17. MECHANISMS FOR CONVERTING ROTARY MOTION INTO RECTILINEAR RECIPROCATING MOTION

The following mechanisms are used in machine tools to convert rotary motion into rectilinear motion: rack and pinion, rack and worm, screw and nut, cam and follower, slider-crank, and crank and slotted rocker arm.

If the pinion of Fig. 34 *a* is rotated on a stationary shaft, the rack will travel in a straight line. On the other hand, reciprocation of the rack, as the driving element, will rotate the pinion which will then be the driven element.

Upon one revolution of the pinion, the rack travels through as many teeth as there are on the pinion. The following relationship exists between the travel S of the rack and the rotation of the pinion:

$$S = tZn \text{ mm per min,} \qquad (16)$$

in which t denotes the pitch of the rack teeth, in mm;

Z denotes the number of teeth on the pinion;

n is the speed of the pinion, in rpm.

Since the module of a gear equals the circular pitch divided by $\pi = 3.14$:

$$m = \frac{t}{\pi} \text{ mm} \qquad (17)$$

formula (16) may be transformed into

$$S = \pi m Z n \text{ mm per min.} \qquad (18)$$

The travel of the rack in Fig. 34 *b* upon rotation of the worm is computed from the formula

$$S = tna \text{ mm per min,} \qquad (19)$$

in which a denotes the number of threads or starts on the worm.

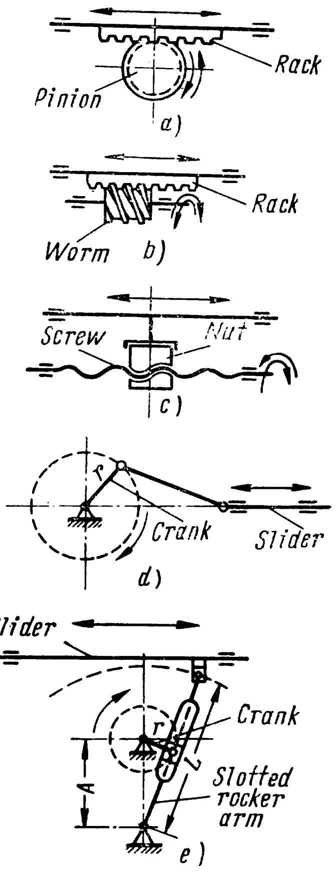


Fig. 34. Mechanisms for converting rotary motion into rectilinear motion.

a — rack and pinion, *b* — rack and worm, *c* — screw and nut, *d* — slider and crank, *e* — crank and slotted rocker arm.

Rotation of a screw, fixed in an axial direction, will cause a nut, held against rotation, to travel in a straight line along the screw. If, on the opposite, the nut is fixed axially and rotated, the screw will travel axially when it is held against rotation.

The following equation will enable the travel of the screw or nut to be determined (depending upon which element is rotated and which travels axially):

$$S=tn \text{ mm per min}, \tag{20}$$

in which t denotes the thread lead in mm;
n denotes the speed of the screw or nut in rpm.

The number of full strokes per minute of the slider-crank mechanism (Fig. 34 *d*) equals the speed in rpm of the driving crank while the slider travel is calculated from the following formula:

$$S=2r \text{ mm}, \tag{21}$$

in which r denotes the radius of the crank, in mm.

The travel of the ram in a crank and slotted rocker arm mechanism (Fig. 34 *e*) is determined from the formula:

$$S=2\,\frac{L}{A}\,r \text{ mm}, \tag{22}$$

in which r denotes the crank radius, in mm;
L denotes the rocker arm length, in mm;
A denotes the distance from the rocker arm pivot to the crank centre, in mm.

Rectilinear reciprocating motion may also be obtained by various hydraulic and electric devices which will be taken up in detail further on.

§ 18. CAM MECHANISMS

Plate (disc) and cylinder (barrel) cams (Figs. 35 and 36) are widely employed to obtain working and auxiliary motions in automatics and semi-automatics.

Cam mechanisms consist of a *cam* and a *follower*. To obtain motion in the required direction and of the required magnitude it is often necessary to arrange intermediate links, chiefly levers, between the cam follower and the final member.

As is evident from Fig. 35, upon rotation of a plate cam, the follower, or the final member, travels up and down (*a*), swings about a pivot (*b*), travels vertically (*c*) or horizontally (*d*). *Plate cams may be expediently employed for motions square with the cam axis.*

The curved edge of a plate cam has its points located at various distances from the centre of rotation and, therefore, the follower will move when the cam is rotated.

Cylinder cams (Fig. 36) are drums having helical slots or cam members. If the cylinder is rotated the follower or the final member will travel horizontally or vertically. *Cylinder cams are usually employed to obtain motions parallel with the cam drum axis.*

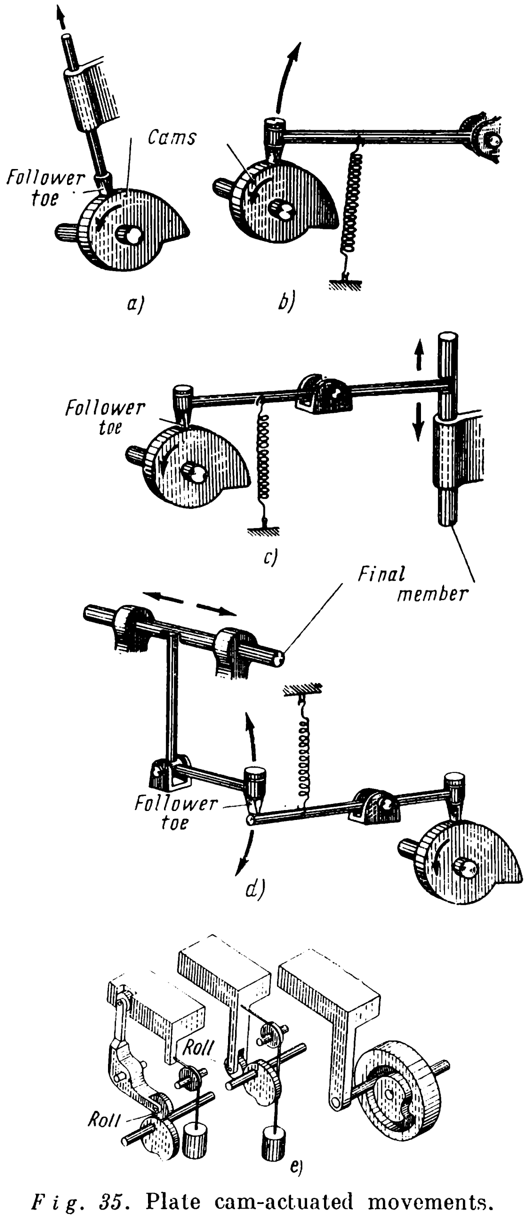


Fig. 35. Plate cam-actuated movements.

a and *b*— vertical movement of follower, *c*— reciprocation of final member, *d*—horizontal movement of final member, *e* — operative units actuated by plate cams.

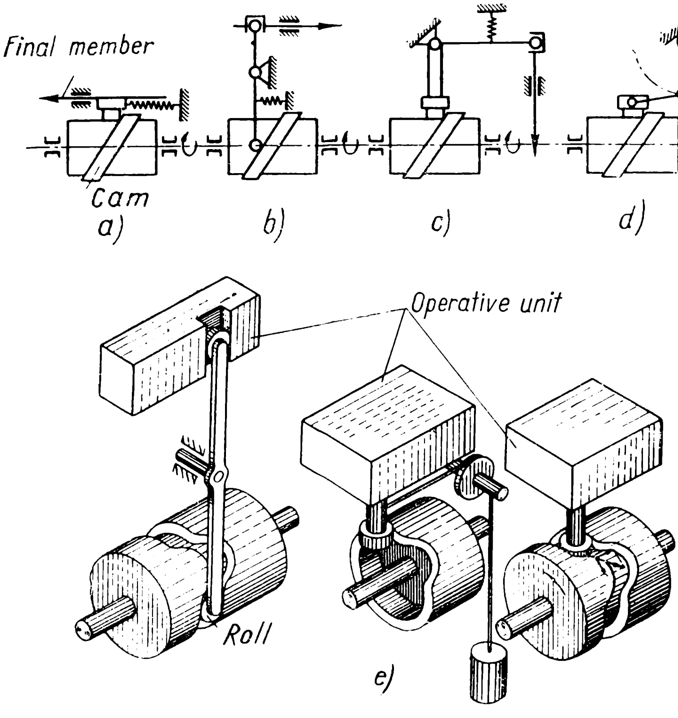


Fig. 36. Cylinder cam-actuated movements.
a and *b* — horizontal movement of final member, *c* and *d* — vertical movement of final member, *e* — most widely used types of cylinder cams.

Cams may be either *single- or two-edged* (Figs. 35 *e* and 36 *e*). Two-edged cams have a curvilinear groove which accommodates the follower roller. Such positive-motion cams provide for positive follower travel in both directions. Single-edge cams actuate the follower in one direction only and depend on some external force produced by a spring or weight to return the follower to its starting point.

Plate cams are of one-piece design and are used for comparatively short travel or strokes.

Cylinder cams for short travel usually comprise a continuous groove milled in a cylindrical drum. For longer travel, cam plates or members are attached by screws to the drum. The magnitude, direction and speed of travel of the operative element (or follower) may be varied by imparting a particular form to the cam edges.

All units of an automatic machine tool must make strictly prescribed motions in a definite sequence for each operating cycle. Such a cyclic sequence of motions may be provided by cam mechanisms.

The form, type, and design of cams are selected not only in accordance with the magnitude, direction and speed of motion required but also with due consideration for the given forces, torques and required duration of the motions.

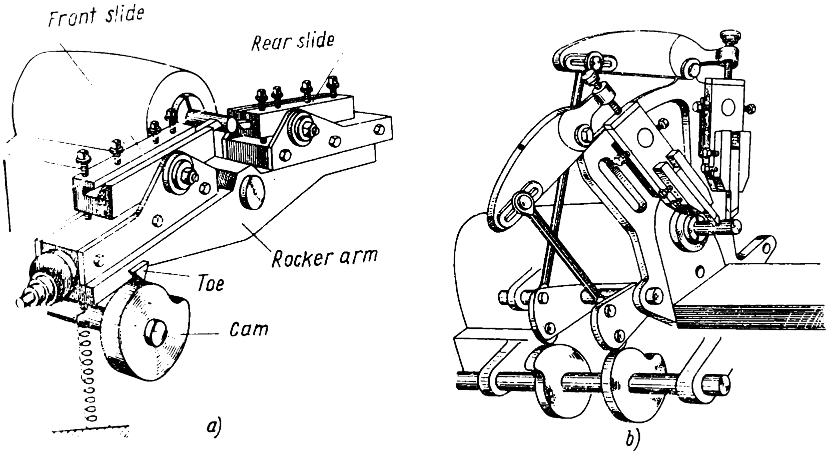
In the design of cams, such factors are to be considered as the permissible size of the cam, the feasibility of its manufacture to the required accuracy, and the necessity of changing or adjusting cams for new setups.

The simplest cam mechanisms are those in which motion is transmitted directly to the operative units of the machine (Fig. 37 *a*).

Since it is not always possible to actuate the operative units of automatics and semi-automatics directly from cam mechanisms, intermediate links, chiefly lever systems, are used (Fig. 37 *b*).

The devices transmitting motion from the cams to the operative units of machine tools must be sufficiently accurate and rigid. Sometimes these devices must provide for the possibility of varying the transmission ratio in a definite range (usually from 1 : 3 to 3 : 1) between the travel of the operative unit and the stroke provided by the cam mechanism.

If levers are not used for setting up by changing their arm lengths, then it is desirable to maintain a transmission ratio of $i = 1$. If the ratio is more than unity, then the travel of the operative unit will exceed the rise of the cam but the accuracy of movement will be reduced. If, on the opposite, the arm lengths provide for a ratio less than unity, the travel of the operative unit will be less than the rise of the cam but errors in the form of the cam will have a lesser effect on the accuracy of movement of the operative unit.



F i g. 37. Examples of cam mechanisms in automatics.
front and rear toolslides arranged on a rocker arm, *b*—vertical toolslides actuated from plate cams through lever systems.

The toolslides shown in Fig. 37 *b* are actuated from cams through adjustable lever systems. This design enables the travel of the slides to be set up to suit the workpiece without changing the cams.

The accuracy with which motion is transmitted and, consequently, the accuracy of motion of the operative units, depends on the accuracy with which the cam form has been manufactured and the cam has been installed. If the cam does not have a smooth working surface, the motion of the slide it actuates will not be uniform and the surface machined on the work will have a poor finish. For this reason, the working edges of cams must be carefully machined to a high finish. Cams are made by first laying out the required outline, removing extra metal by drilling a series of holes near the outline and breaking off the extra parts or by sawing out or gas-cutting the required form. The outline is then finish machined on a universal or special milling machine.

If highly accurate cams are required, the milled edge is filed and roughly lapped. Finish lapping is done after heat treatment. The outline of precise cams should be checked with special fixtures which measure the outline at each angular point of their rotation.

Accurately ground mounting holes and rigid fastening are required for precise installation of cams.

Cams and especially dogs are also used on automatics and semi-automatics for tripping various devices and for stopping various units or elements. In this case, their design does not depend on the workpiece.

§ 19. CAMSHAFTS

The camshaft of a machine carries cams which trip various control units during rotation of the camshaft and actuate the required movements of each unit during the operating cycle. These cams provide for the complete cycle of working and auxiliary motions of the machine. In some cases, the camshaft consists of several separate branches (Fig. 38) to provide more convenience in actuating the various units.

The cams mounted on a camshaft are usually designed so that one revolution of the camshaft provides for one complete cycle and, consequently, the time required for one revolution of the camshaft is the time required to produce one workpiece. This time is called the *cycle time* (T_c) of the machine.

To calculate the number of workpieces produced per minute, hour, or shift it is sufficient to know the number of revolutions the camshaft makes in this period of time or the cycle time in seconds. Then the rate of production Q_m per minute or hour may be

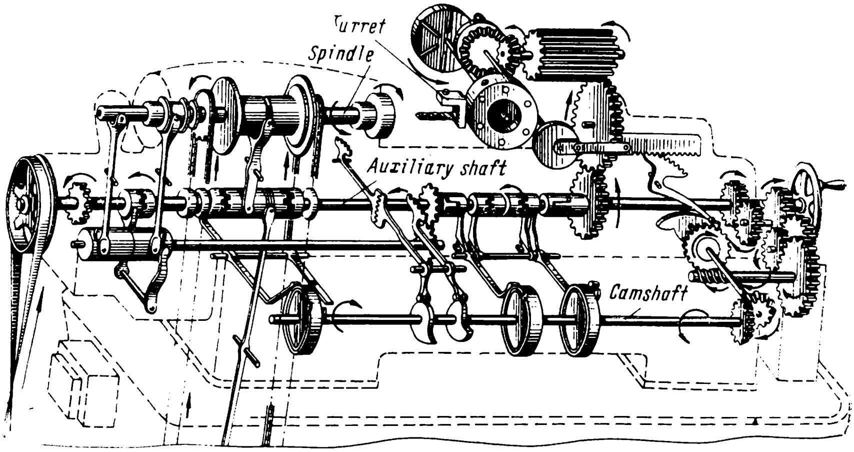


Fig. 38. Camshaft with cam mechanisms.

determined from the formulas:

$$Q_m = \frac{60}{T_c} \text{ pcs per min,} \tag{23}$$

$$Q'_m = \frac{3{,}600}{T_c} \text{ pcs per hr.} \tag{24}$$

If several workpieces are finished in a single cycle of an automatic, the number produced in a given period of time may be determined by multiplying the results obtained in formula (23) or (24) by the number of workpieces (p) finished in one cycle, i. e.,

$$Q_m = p\frac{60}{T_c} \text{ pcs per min,} \tag{25}$$

$$Q'_m = p\frac{3{,}600}{T_c} \text{ pcs per hr.} \tag{26}$$

The workpiece is loaded, clamped and removed and the operation cycle is started manually on semi-automatic lathes. For multiple-spindle semi-automatics, these manual operations often coincide in time with the machining operations simultaneously performed in the other spindles. If, however, these times do not coincide, the time required to produce one workpiece will be the sum of the cycle time plus the time required for the manual operations which are not covered by the working cycle.

Since various work may be produced on general-purpose automatics and semi-automatics, the machine time will vary. Therefore, *a setting-up element must be included in the camshaft drive which will enable the required camshaft speed to be obtained so as to suit the production cycle time.*

§ 20. MECHANISMS FOR PERIODIC (INTERMITTENT) ROTATION

Periodic rotation mechanisms include a stop with pins (Fig. 39 *a*), ratchet devices combined with crank or cam mechanisms (Fig. 39 *b* and *c*) and Geneva mechanisms (Fig. 40).

A driven shaft may be periodically indexed through a definite angle by means of a Geneva mechanism. Upon rotation of the revolving arm, the roller enters the slots of the Geneva wheel, one after another, and indexes the wheel each time through an angle equal to the angle between adjacent slots.

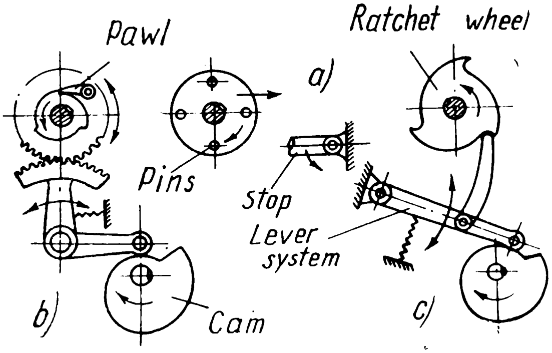


Fig. 39. Mechanisms for periodic rotation.
a — stop with pins, *b* and *c* — ratchet devices combined with cam mechanisms.

Therefore, if it is necessary to index the driven shaft periodically through 1/4 revolution, i. e., 90°, the Geneva wheel must have four slots (Fig. 40 *a*). For six slots, the driven shaft is indexed through 1/6 revolution, i. e., 60°, etc.

If intermediate gearing is arranged between the Geneva wheel and the unit which is to be periodically indexed, the angle of rotation of the camshaft may be increased or decreased in relation to that of the Geneva wheel shaft (Fig. 40 *b*). This design is more expedient in most cases.

For example, a four-slot Geneva wheel will be indexed 90° each time but if spur gearing with a ratio $i_1=\frac{4}{3}$ (Fig. 40 *b*) is arranged between the wheel and the subsequent shaft, the angle through which the second shaft is indexed will be $90^\circ\times\frac{4}{3}=120^\circ$. If $i_2=\frac{1}{2}$, the last shaft will be indexed through $120^\circ\times\frac{1}{2}=60^\circ$.

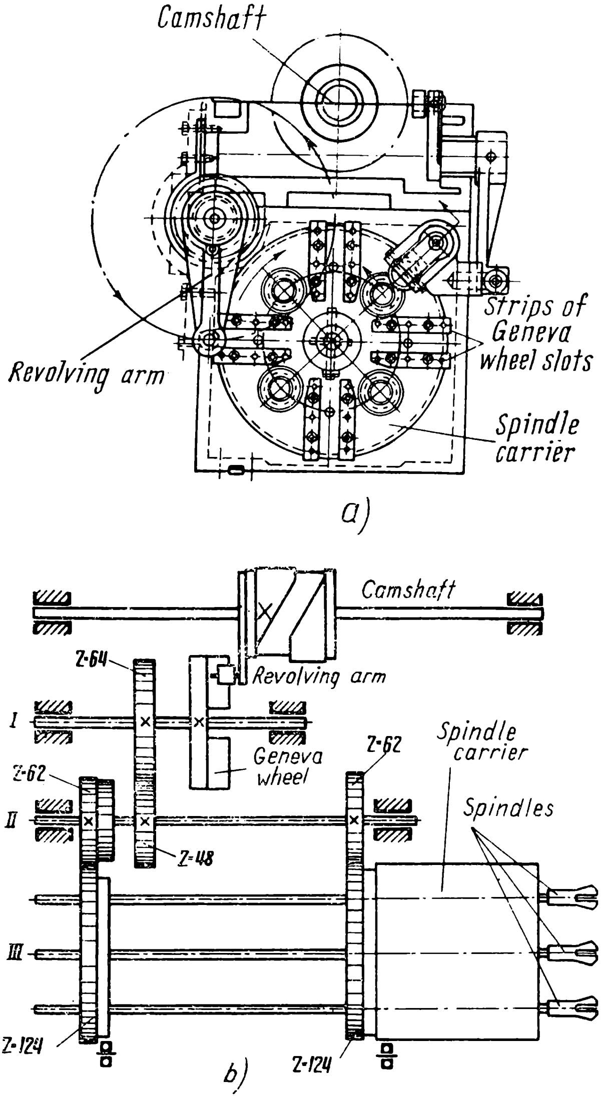


Fig. 40. Geneva mechanisms.
a—direct action, *b*—through intermediate gearing.

§ 21. LOCKING

Locking devices are employed if a unit is to be precisely positioned after indexing and is to maintain this position during the next period of operation.

As a rule, the locking device (locking pin) has one inclined and one straight locating face (Fig. 41). Under the action of a spring, the locking pin enters its slot and begins to rotate the unit to be locked (turret, spindle carrier, or table).

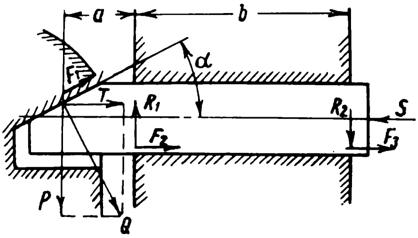


Fig. 41. Forces acting on a locking pin.

S — actual force exerted to seat the locking pin, P — tangential force overcome by pin, Q — force acting normally to inclined surface of unit being locked, T — component of normally-acting force directed along axis of locking pin, R_1 and R_2— reactive forces in guiding surfaces of locking pin, F_1, F_2, and F_3— friction forces.

This rotation ends when the straight locating face of the locking pin seats tightly on the straight face of the slot. The forces acting on the locking pin are shown schematically in Fig. 41.

A spindle carrier may be *locked* with *one locking pin in a single-locking system* (Fig. 42) or with *two locking pins in a double-locking system* (Fig. 43).

In the action of a double-locking system, one locking lever serves as a positive stop and has a straight locating face. The second locking lever has an inclined face which turns the unit being locked to seat against the first locking lever. When the unit is released from the action of the locking devices, the second lever is positively withdrawn from its slot while the first is pushed out by the unit itself.

Double-locking ensures a more precise and stable position of a spindle carrier and is applied in all the latest models of Soviet automatics.

The newest models of semi-automatic turret lathes and multiple-spindle automatics have special devices for clamping indexed units such as turrets, spindle carriers and tables.

The unit is clamped after the locking pin establishes the precise angular position. The clamping device may be designed as a yoke or shoe which forces the rotating member against the locating surface of the base.

The spindle carrier of multiple-spindle automatics and semi-automatics is automatically lifted slightly above its locating surfaces, after withdrawing the locking pin, to eliminate wear and to maintain the initial precision of the carrier.

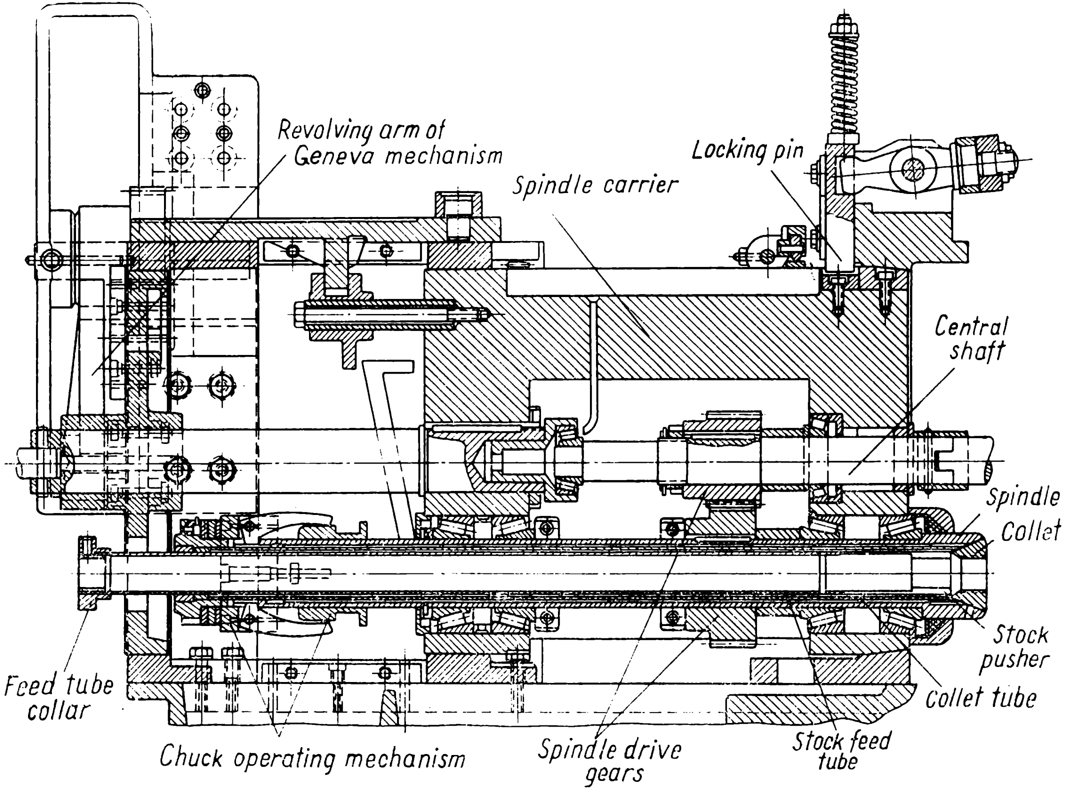
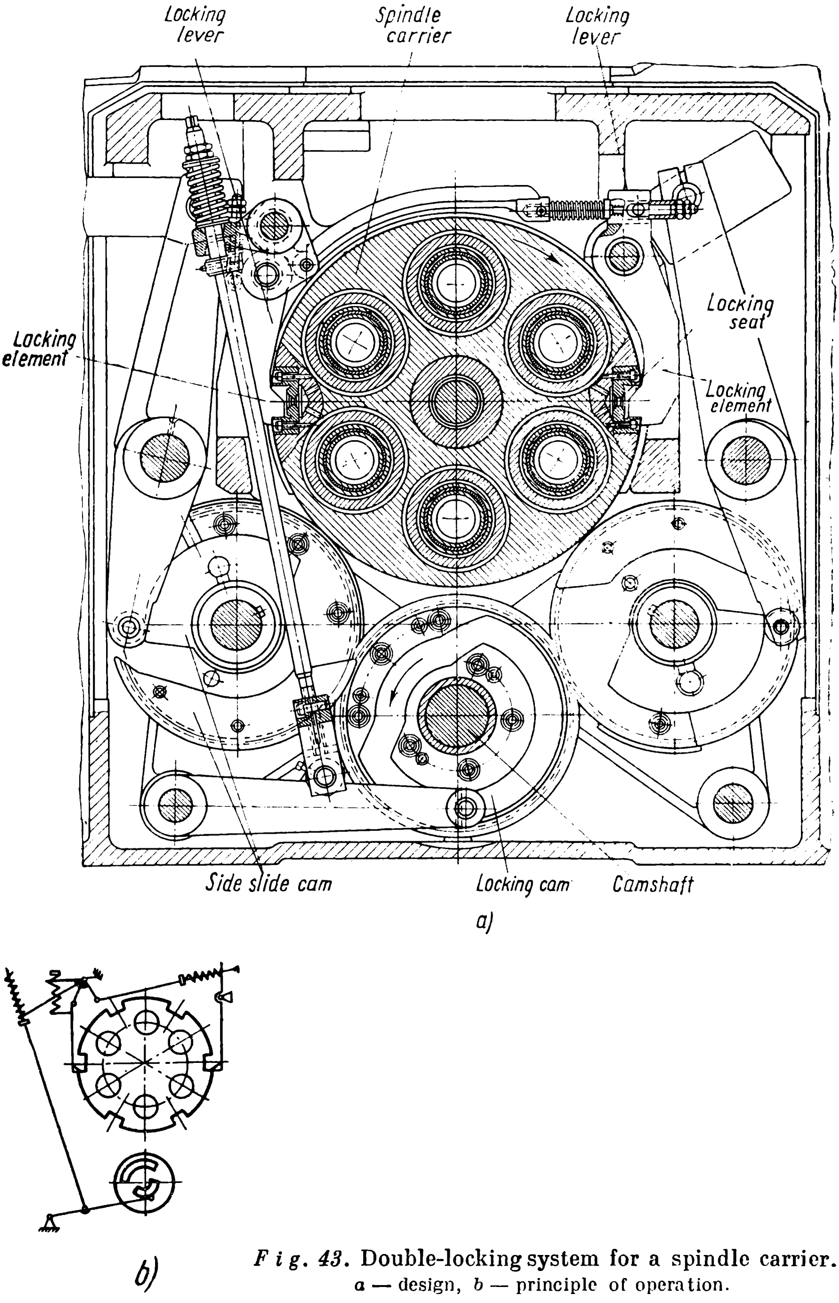


Fig. 42. Single-locking system for a spindle carrier.



F i g. 43. Double-locking system for a spindle carrier.
a — design, *b* — principle of operation.

§ 22. ENGAGING AND DISENGAGING MECHANISMS

The principal types of mechanisms for engagement and disengagement are couplings for permanently joining two shafts and clutches for temporarily connecting a rotating element to a driving member (for example, a gear to a shaft). Clutches serve for disengagement and are further classified as jaw and friction clutches.

Jaw clutches consist of two members having teeth or jaws on their end surfaces. One member is rigidly linked to one element and the other clutch member slides along a key or splines of a second transmission element. The second member may be shifted axially until the jaws (teeth) of the two members engage each other.

Jaw clutches may be used for engaging running shafts if the difference in speeds between the driving and driven shafts is not excessive (not over 200 rpm).

Jaw clutches which engage shafts for only a part of a revolution or for one complete revolution are called *automatic single-revolution clutches*. The most widely used design of this type of clutch is illustrated in Fig. 44. It operates in the following manner: gear *1* is to be rotated one revolution by the rotating shaft *4* and is then to be automatically disengaged. Long jaws are provided on the end of gear *1* and clutch member *2* so that they will not disengage when member *2* is shifted to engage the jaws, on the right end of this member, with the jaws of disc *3*, linked rigidly with shaft *4*. In the disengaged position, clutch member *2* is retained by the lock pin *9*. If the lock pin *9* is withdrawn from its slot, the spring will force the clutch member to the right and into engagement with disc *3*. This causes the gear to start rotating. The lock pin *9* will slide along the external surface of clutch member *2* until it drops into recess *AB*. This recess has a beveled surface which forces the clutch member, upon further rotation, toward the left to disengage the gear from the rotating disc *3*. The lock pins *5* and *9* are backed by the springs *7* and *8*. The single-revolution clutch is controlled from a cam mechanism of the camshaft through a lever system.

Friction clutches (Fig. 45 *a* and *b*, see also Fig. 29). Their operation is based on forcing the two clutch members together so that a friction torque is developed between the contacting surfaces. This torque will cause the driven member to rotate when the driving member is rotated.

Friction clutches are classified as cone (Fig. 29) and disc types (Fig. 45). As their name implies, in cone clutches the friction surfaces are conical in form.

In disc clutches, a part of the flat discs are secured in a housing mounted on one shaft. The rest of the discs, located alternately so that each disc is between two of the first discs, are secured to a second shaft. If an axial force is applied to all the discs, the pressure between them will develop a friction torque which will rotate the driven shaft.

The more discs provided and the larger their diameter, the larger the friction torque developed and the higher the power that may be transmitted, all other conditions being equal.

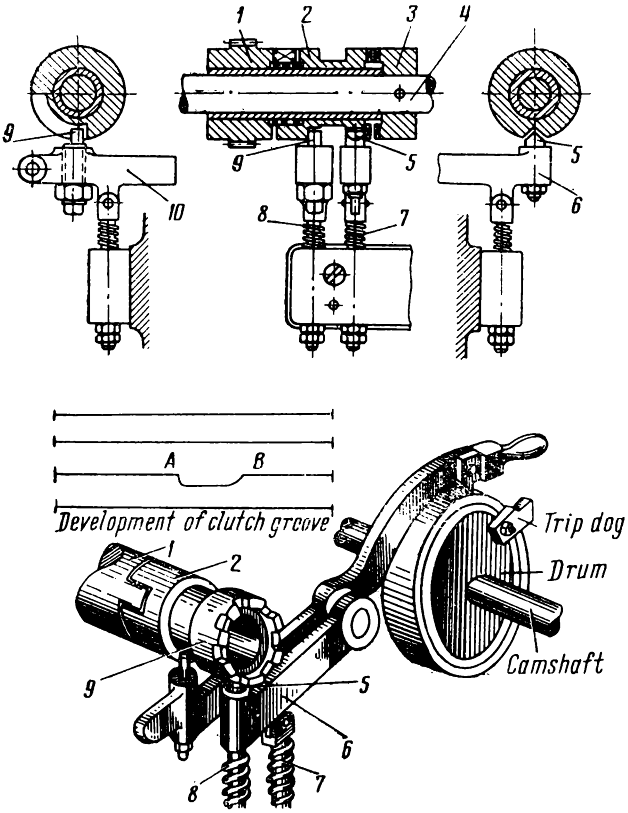


Fig. 44. Single-revolution clutch.

1 — gear with jaws on end face, *2* — left-hand member of jaw clutch, *3* — right-hand member of jaw clutch, *4* — shaft, *5* — lock pin on lever *6*, *7* and *8* — springs, *9* — lock pin on lever *10*.

Friction clutches are often used in cases when it is necessary to engage or disengage the driven shaft, to change its speed or its direction of rotation without stopping the driving shaft.

Let us consider two shafts, driving and driven. The driven shaft is to be rotated at two different speeds and is to be switched from one speed to the other without stopping the driving shaft. For this purpose, two gears are rigidly mounted on the driving shaft which mesh with two gears mounted freely on the driven shaft.

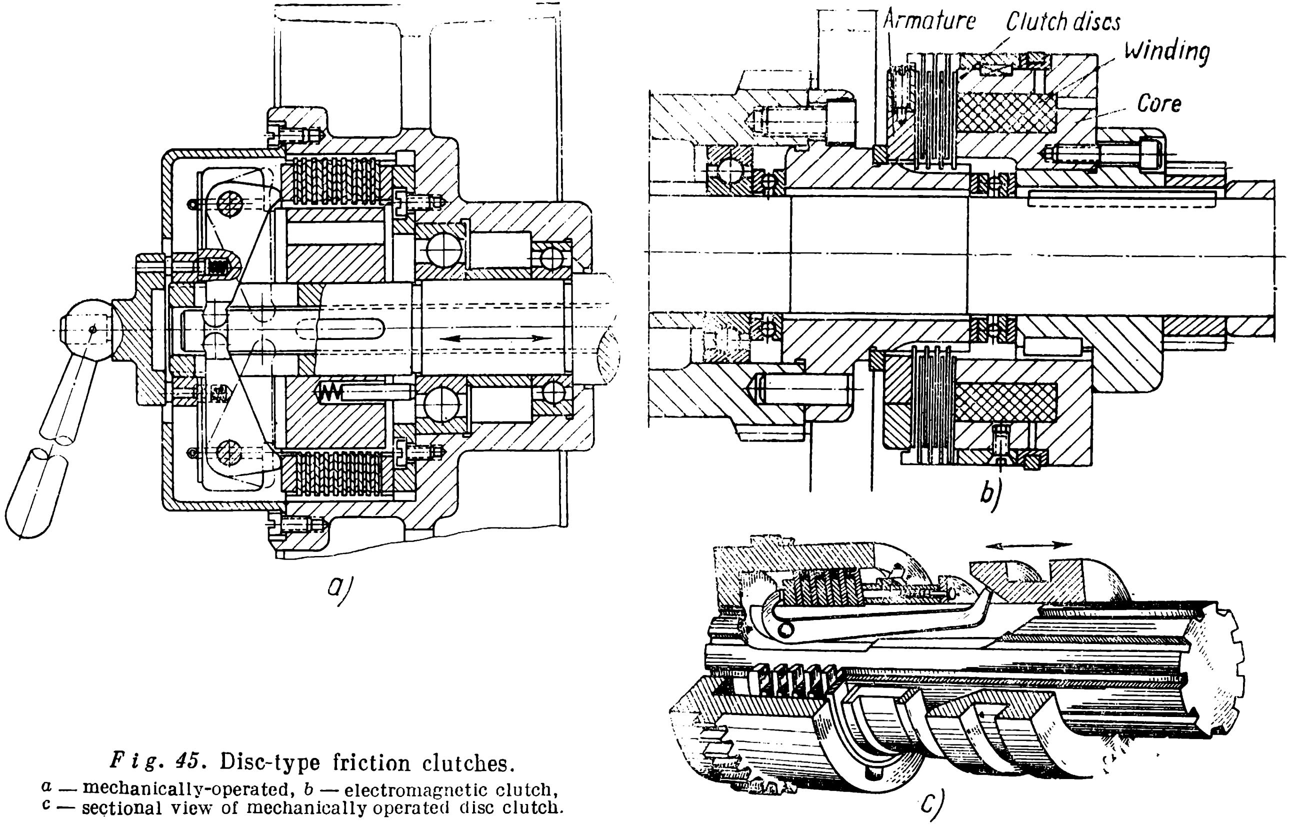


Fig. 45. Disc-type friction clutches.

a — mechanically-operated, *b* — electromagnetic clutch, *c* — sectional view of mechanically operated disc clutch.

The gearing ratio of each pair of meshing gears is selected to give the required two speeds to the driven shaft. Each of the freely mounted gears may be engaged to the driven shaft by a friction clutch. When the clutch is disengaged, the driven shaft will not rotate. If the friction clutch, linked rigidly to the driven shaft, is shifted to the left to engage the left-hand gear, the driven shaft will rotate at one of its speeds, if the clutch is shifted to the right to engage the right-hand gear, the driven shaft will rotate at a different speed.

A sectional view of a friction clutch is shown in Fig. 45 *c*.

Friction clutches are often applied for automatic engagement and disengagement of driven elements (see Fig. 29).

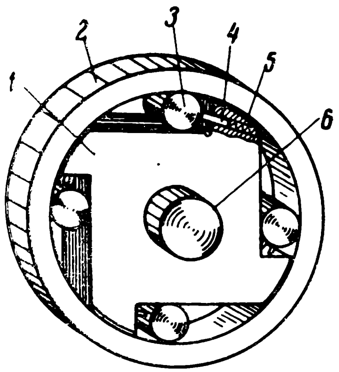


Fig. 46. Overrunning clutch and its principle of operation.
1 — inner member, *2* — shell, *3* — rollers, *4* — pins, *5* — springs, *6* — shaft.

An electromagnetic multiple-disc friction clutch (Fig. 45 *b*) operates on the following principle: when the winding is connected to a 12 or 24 V power supply, a magnetic flux is created which passes through the steel discs and the armature and forces the friction discs together to link together the driving and driven elements of the transmission.

Overrunning or free wheeling clutches (Fig. 46) are widely employed in automatics and semi-automatics to transmit slow working

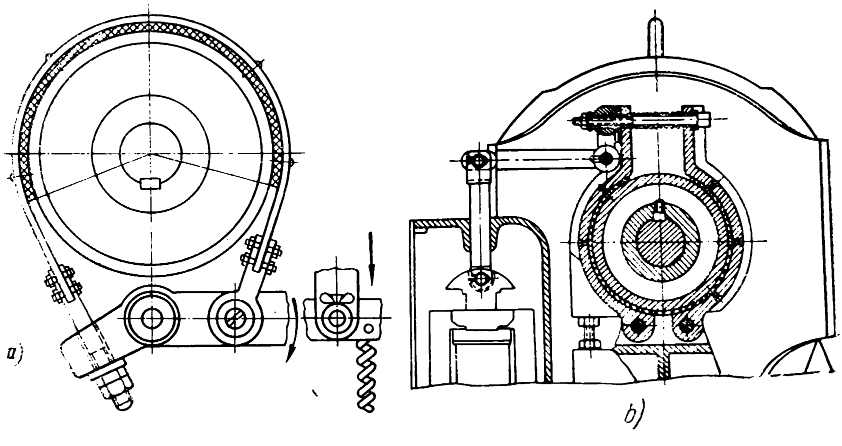


Fig. 47. Brakes.
a—band brake, *b*—shoe brake operated by a solenoid.

rotation and rapid auxiliary (idle) rotation to a shaft (working feed and rapid traverse movements). If the inner member *1* is rotated rapidly in a counter-clockwise direction, the rollers *3* will not jam. This will disengage all linkage between the slowly rotating shell *2* and shaft *6* which will rotate rapidly. If, then, the rotation of the inner member *1* is switched off, the rollers will roll to the narrow end of their recesses and jam so that shell *2* will drive shaft *6*.

Certain designs of overrunning clutches allow rotation in either direction.

Brakes (Fig. 47) are used for stopping a disengaged element of the drive. The action of a brake is based on application of a frictional force to a rotating element. This will create a friction torque which will rapidly reduce the speed and finally stop the driven shaft.

Electric and hydraulic devices are extensively employed, in addition to clutches, for engagement, disengagement, and braking.

§ 23. SPEED-CHANGING ELEMENTS

Automatic and semi-automatic lathes are designed for machining a great variety of parts and, therefore, speed-changing facilities are necessary elements of their drives.

Speed changes of rotating or reciprocating components may be made when setting up the machine, i. e., when the machine is not in operation. It is often necessary to change speeds or feeds during the time the work is being machined, i. e., within the operating cycle.

Change gears and sliding gears. Speeds are manually changed in setting up a machine tool, in some cases, by engaging and disengaging clutches and brakes.

In setting up a machine tool, the required speeds may be obtained by installing the proper change gears (Fig. 48 *a*), by manually switching over a clutch which engages freely mounted gears to the driving or driven shafts (Fig. 48 *b*) or by shifting sliding gears (Fig. 48 *c*). In the selection of change gears mounted on two shafts, the sum of the numbers of teeth on the various pairs of gears (of the same module) must remain constant.

Example: If the sum of the numbers of teeth of change gears is 80 then the following combinations may be used:

Number of teeth	driving gear	20	21	22	23	. . . . . .	60
	driven gear	60	59	58	57	. . . . . .	20
Total number of teeth		80	80	80	80	. . . . . .	80

The gearing ratio of change gears is usually not over 2 : 1 and not less than 1 : 4.

Change gears are usually mounted on the outer overhanging ends of shafts. For this reason they can be removed and a new pair installed with a minimum time loss, usually not over 1 to 2 min. Change gears must be secured reliably on their shafts so that there is no danger of them slipping off in operation. They may be changed only after switching off the drive of the machine tool.

Sliding gears may be shifted only with the rotation of the driving shaft switched off or disengaged. If a double-cluster gear (Fig. 48 *c*) is shifted so that one of the gear rims of the cluster gear meshes with one of the gears on the second shaft, one of the two available speeds of the driven shaft may be obtained.

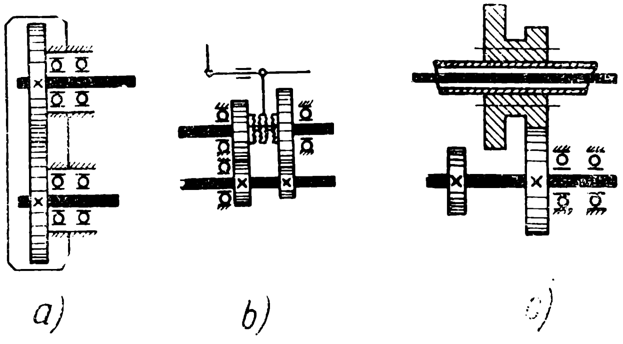


Fig. 48. Speed changing devices.
a — with change-gears, *b* — with clutches engaging gears, *c* — with sliding gears.

Shaft rotation may also be reversed by means of clutches and sliding gears. Friction clutches are most frequently employed for automatic speed adjustment during the operating cycle.

Infinitely variable frictional speed-changing drives of various designs (Fig. 49) are used in machine tool engineering. They are based on the following principle: the driven link contacts the driving link either directly or through some intermediate element (roller, disc, ring, or belt). The driven and driving elements are held tightly together and the frictional force developed will cause one element to rotate when the other is rotated. If the diameter of contact on both the driving and driven elements or on at least one of them can be varied, then the transmission ratio of the drive will vary accordingly.

Fig. 49 *a* and *b* illustrates infinitely variable frictional speed-changing drives having two cones and an intermediate element. The speed of the driven shaft may be varied (with the driving shaft rotating at constant speed) by shifting the roller or ring along the cones. This adjustment may be made within the limits of variation of the radii on the driving *(dr)* and driven *(dn)* elements:

$$\frac{r_{min_{dr}}}{r_{max_{dn}}} \text{ to } \frac{r_{max_{dr}}}{r_{min_{dn}}}.$$

Infinitely variable speed-changing devices with two perpendicular shafts are shown in Fig. 49 *c* and *d*. Disc *1* with a radius of r_1 is mounted on the driving shaft. This disc may be set at different axial positions on its shaft contacting disc *2* of the driven shaft at various points (r_2 is variable). Speed adjustment may be made in the limits from

$$\frac{r_1}{r_{2_{max}}} \text{ to } \frac{r_1}{r_{2_{min}}}.$$

An infinitely variable speed-changing device with spherically-shaped discs is applied in the kinematic diagram shown in Fig. 50.

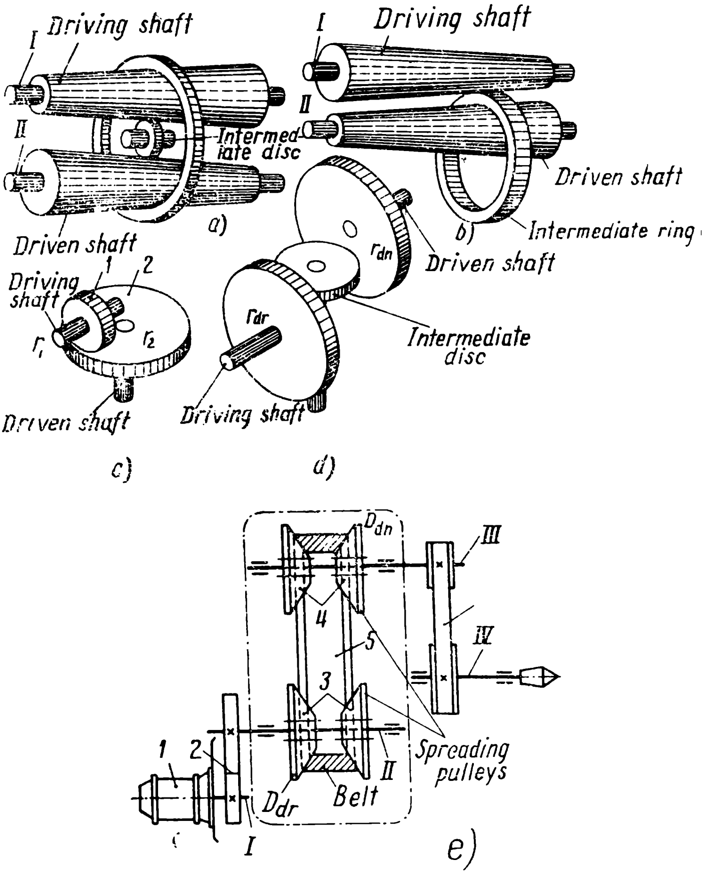


Fig. 49. Infinitely variable frictional speed-changing drives.

Friction rollers, arranged between the spherically-shaped discs on the driving and driven shafts may be inclined in different positions. This will change the radii of contact between the roller and the driving and driven discs as shown at the top of Fig. 50.

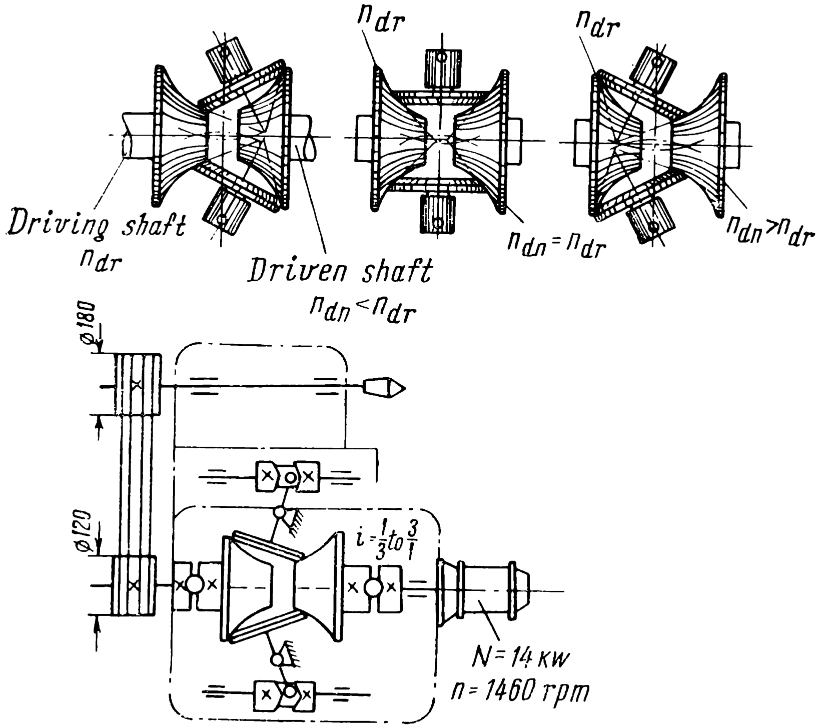


Fig. 50. Infinitely variable frictional speed-changing drive.

CHAPTER III

ELECTRIC AND HYDRAULIC DRIVES

§ 24. ELECTRIC DRIVES AND ELECTRIC MOTORS

The trend in the development of machine tool drives has been toward more complete motorisation. The electric drives of machine tools comprise one or several drive motors and devices for their control (starting, interlocking and signalling devices).

Soviet automatics and semi-automatics have separate (individual) motors for the main drive, working and rapid traverse of the principal units.

Previously, spindle speeds and rates of feed were changed only by changing the transmission ratio of the gear train. At the present time, speeds and feeds are often varied by electrical methods. Up-to-date electric motors can easily be reversed or braked.

In Soviet machine tools, electrical devices are extensively employed for clamping the work, for providing protective and safety devices, for control, checking, signalling and work lighting.

The importance of electricity in the automation of machine tool operation and in checking the operating cycle is of special note.

The motorisation of machine tools and an ever wider use of electric controls will continue to be one of the principal factors in their improvement, in increasing the rate of production and reliability of machine tools and in reducing operator fatigue.

Electric motors are characterised by their rated power in horse power (hp) or kilowatts (kw), their rated shaft speed (rpm), torque developed by the motor during starting (starting torque), type of power supply current, its normal voltage and its frequency in cycles per second. An index plate containing this data is provided on each motor.

Three-phase squirrel cage motors for a power supply of 220/380 or 500 V, 50 cps are most frequently employed in machine tools.

Such motors have a flat characteristic, i. e., their speed falls only slightly with an increase of load. Three-phase electric motors have speeds in rpm near to the following series: 3,000, 1,500, 1,000, 750, 600 and 500.

Ordinary three-phase electric motors have only one shaft speed. Their direction of rotation may be readily changed (either clockwise or counter-clockwise). Two-, three-, and four-speed three-phase motors have two, three, or four speeds which may be switched over either manually or automatically.

Shunt-wound direct current motors also have a flat characteristic. The speeds of these motors are usually infinitely variable in a speed range ratio of 3 or 4, i.e., the ratio of the maximum to the minimum speed will be 3 or 4.

The main advantage of shunt-wound direct current motors is that their speeds are infinitely variable (practically with a very small difference—4 to 5 per cent—between adjacent steps).

Electric motors permit momentary overloads up to 1.5 or 2 times the rated values. This feature is used in starting a motor since a considerable overload is experienced at this time. If the design of the machine tool requires the drive motor to be switched on and off frequently, it will be necessary to check whether the motor permits the required switching frequency per minute or per hour.

§ 25. ELECTRIC CONTROL DEVICES

Electric control devices are classified as manually-operated and automatic.

Manually-operated electric control devices include knife switches, rotary switches, drum switches, magnetic starters with push-button controls, and push-button stations.

Knife switches serve as main line switches for connecting the electric circuit of the machine tool to the power supply. They may be of the single-, two-, and three-pole types and are applied for low switching frequencies. These switches are available in casings to safeguard the operator against electric shocks.

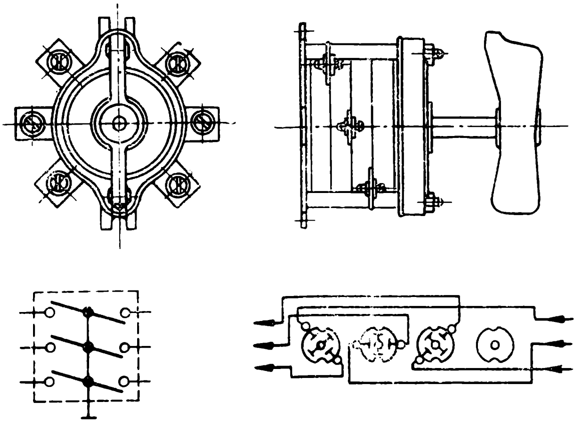


Fig. 51. Three-pole rotary switch.

At the present time, knife switches have been replaced to a great extent by more efficient devices: *rotary switches* for low power requirements (Fig. 51) and special starters for high power values.

Drum switches (Fig. 52 *a*) are chiefly used for controlling multiple-speed motors.

Magnetic starters with push-button controls (Fig. 52 *b*) are the most convenient and widely used devices for the control of three-phase electric motors.

Push-button stations are located on machine tools within easy reach of the operator. The push-buttons (Fig. 52 *c*) may have various purposes. A single station may accommodate “Start”, “Stop”, “Forward”, “Reverse”, and other push-buttons.

Automatic electric control devices include magnetic starters, limit switches, rotary master switches, electromagnets, and various types of relays.

Limit switches (Fig. 53) will automatically switch on, reverse, or switch off the movements of various units of a machine tool.

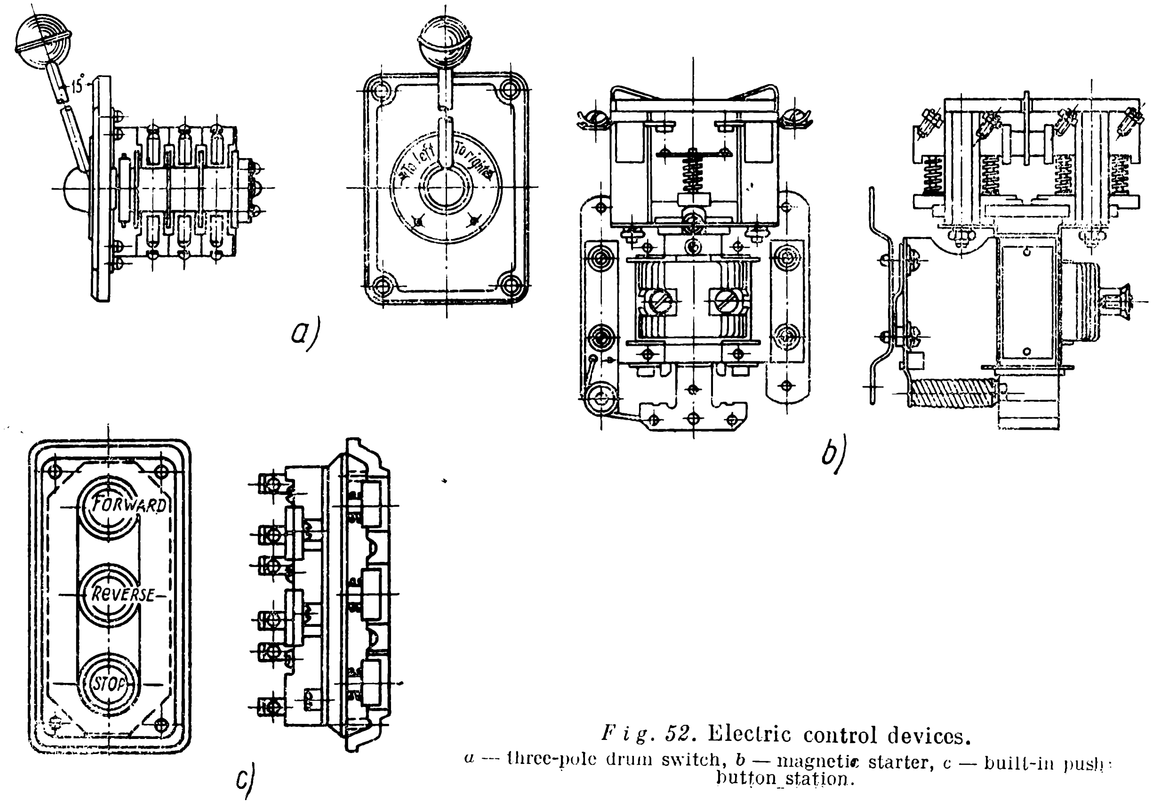


Fig. 52. Electric control devices.

a — three-pole drum switch, *b* — magnetic starter, *c* — built-in push-button station.

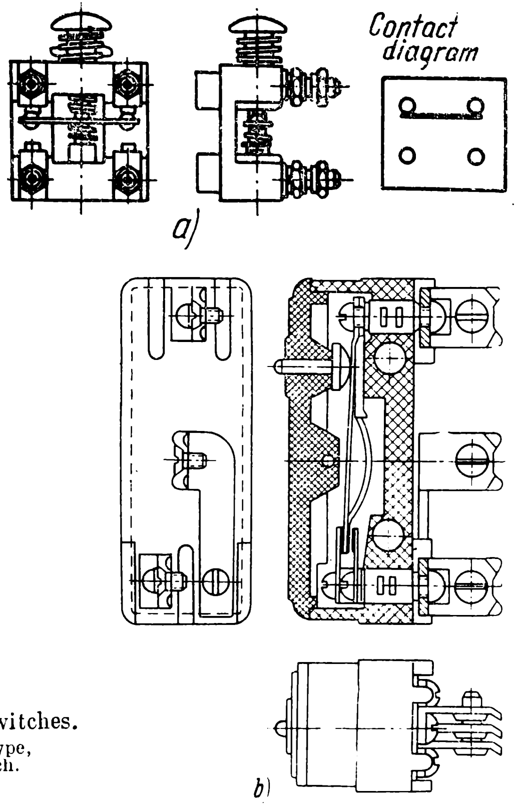


Fig. 53. Limit switches.
a — ordinary type,
b — micro-switch.

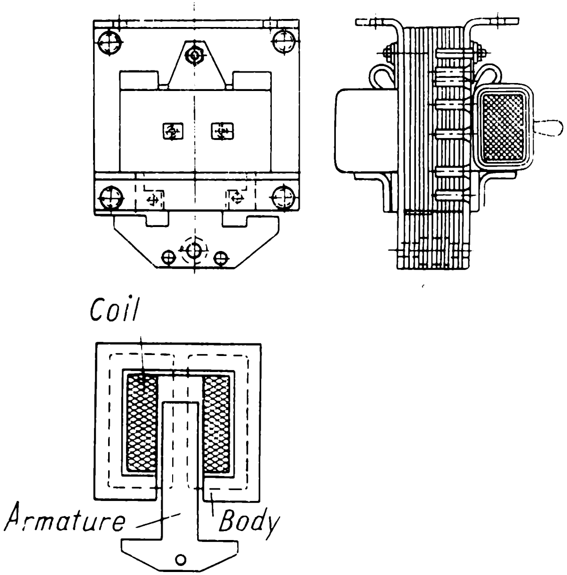


Fig. 54. Solenoid.

travelling components may depress the spindle of the limit switch to open certain contacts and to close other contacts.

Rotary master switches serve to control an automatic sequence of movements in machine tools. Drum-type master switches are similar in design to drum switches shown in Fig. 52 *a*.

Electromagnets (solenoids) (Fig. 54) are used mainly for actuating control devices of a machine tool if the corresponding electric circuit is closed with a limit switch or other device. When a solenoid is switched on its electromagnet is energised and pulls in the core. If this core is linked to a mechanical, hydraulic or electric control device, the latter will be actuated and the required action will be automatically performed.

Relays serve for switching other devices on or off when a limit switch is tripped, when the voltage or current changes in a circuit and even upon changes in pressure in a hydraulic system or upon temperature changes. Certain relays count off a definite period of time and then switch some other device on or off as required.

Relays are usually classified as protective and control types.

Protective relays are employed as means of protection, i. e., they trip automatically to protect the electrical system against breakdowns due to abnormal conditions.

Control relays switch various motions of the machine tool on or off as prescribed by the operating cycle.

Thermal and maximum current relays protect electric motors against dangerous overloads.

§ 26. ELECTRIC TRACER-CONTROL UNITS

Electric tracer-control units are employed on automatic and semi automatic lathes to reproduce a given contour on a workpiece. The main element of a tracing system is the tracer which may be a sensitive finger (stylus) or a beam of light (in electronic systems). The stylus follows the profile of a two-dimensional template or the contour of a three-dimensional model, or the light beam follows the outline of a drawing or flat template and regulates the movements of a cutting tool clamped on a slide so that the form being traced will be reproduced or duplicated on the work being machined.

The electrical tracer head shown in Fig. 55 *b* may be employed for following the profile of a template. The stylus *1* is located in the body *2* on a ball joint. The form of the template followed by the tracer may deflect the stylus downward or to any side about the centre of the joint. The lower end of the rod *3* enters a recess in the slide block *4* and deflects the lever *6*. Due to the action of spring *5*, initially rod *3* is held in its upper position with the contacts *7* closed. Pressure of rod *3* on lever *6* will open contacts *7* and close contacts *8*.

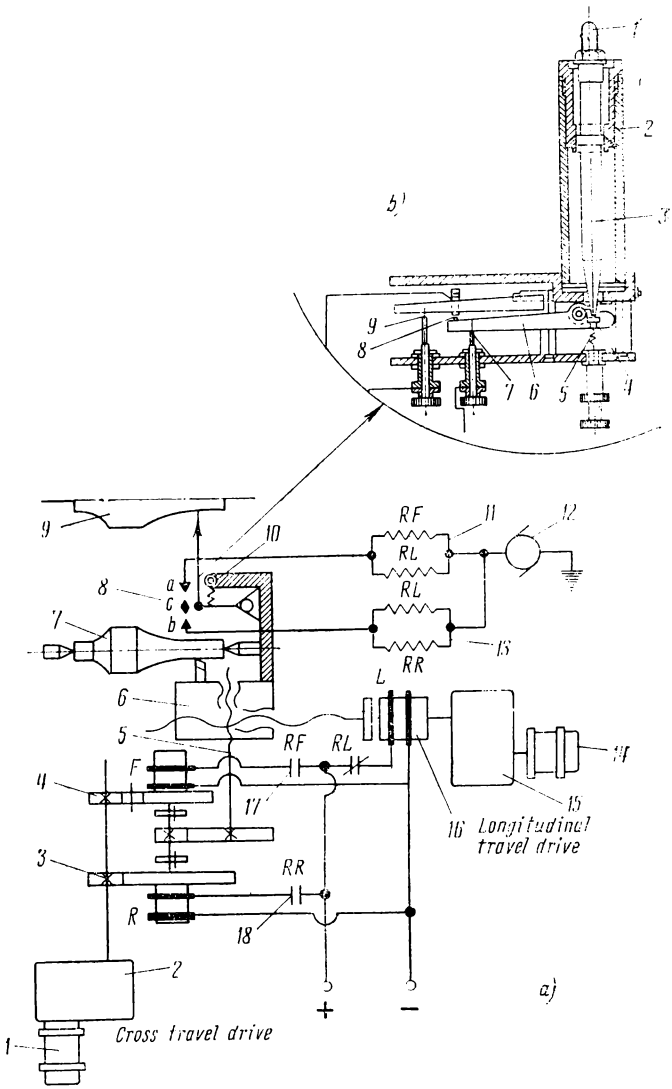


Fig. 55. Electromechanical tracer-controlled slide drive.

a — line diagram: *1* — cross feed drive motor, *2* — speed gearbox, *3* — gearing for slide feed away from work, *4* — gearing for slide feed toward work, *5* — cross feed screw, *6* — toolslide, *7* — workpiece, *8* — tracer head, *9* — template, *10* — bracket mounted on the toolslide, *11* — "Forward" electromagnetic relay, *12* — generator for supply of amplifying devices, *13* — "Reverse" electromagnetic relay, *14* — longitudinal feed drive motor, *15* — speed gearbox, *16* — coupling and lead screw, *17* — contacts "Slide-Forward", *18* — contacts "Slide-Reverse", *RF* — relay "Forward", *RR* — relay "Reverse", *RL* — relay "Longitudinal Feed"; *b* — diagram of tracer head: *1* — stylus, *2* — body, *3* — rod, *4* — slide block, *5* — spring, *6* — lever, *7*, *8*, and *9* — contacts.

An excessively large deflection of rod *3* and lever *6* will open contacts *9* which will switch off all movements of the machine. In this manner, the tracer head transmits work signals to the slide travel drive in accordance with a short section of the template profile.

The principle of operation of an electrically-controlled tracer system for a lathe is illustrated in the line diagram (Fig. 55 *a*). Here the workpiece *7* is to be contoured to the profile of the template *9*. Longitudinal feed of the carriage is obtained from motor *14* through speed gearbox *15*, coupling and lead screw *16* and is constant during operation. A tracer head *8* is mounted on bracket *10* of toolslide *6*. If the stylus of the tracer head *8* is deflected downward by the template *9*, contacts *c* and *b* will be closed. This will energise electromagnetic relay *13* which, in turn, will close contact *18* to engage the magnetic clutch *R* of gearing *3*. In this case, rotation will be transmitted from the cross feed motor *1* through the speed gearbox *2*, gearing *3* and a pair of constantly-engaged gears to the cross feed screw *5* which withdraws the toolslide *6* from the work. If, on the other hand, contact is lost between the stylus of the tracer head *8* and the template *9*, the spring will close contacts *c* and *a*. This will energise the "Forward" electromagnetic relay *11* which, in turn, will close contact *17* to engage magnetic clutch *F* of gearing *4*. Now rotation will be transmitted from motor *1* to cross feed screw *5* through gearing *4* which has an intermediate gear. Therefore toolslide *6* will advance to the work. Work signals will be transmitted from the tracer head in small periods of time and, for this reason, the contour turned on the workpiece will correspond to the profile of the template except that it will have fine steps. The smaller the longitudinal feed and the more sensitive the tracer unit (or system), the smaller will be the steps and the smoother the surface obtained.

§ 27. HYDRAULIC DRIVE FUNDAMENTALS

Hydraulically-operated systems are widely used for obtaining working and auxiliary motions, as well as for actuating controls. The advantage of a hydraulic drive is in the rapid and infinitely variable adjustment of the length, speed and direction of travel of a machine tool unit that may be obtained during operation. Besides this, hydraulic drives enable the most complex automatic cycles to be obtained simply.

A hydraulic drive for straight line motion comprises *a pump, delivering oil under pressure, a distributing device and an operating cylinder with a piston and piston rod. Either the cylinder or the rod is linked to the operative unit of the machine tool and the other is stationary.*

If, for example, oil under pressure is delivered to the left-hand end of the cylinder, shown in Fig. 56, the piston and rod will move to

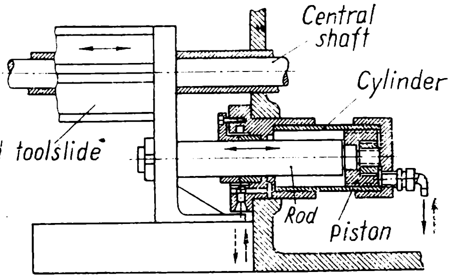


Fig. 56. Piston travel in a hydraulic cylinder.

the right and oil from the right-hand end of the cylinder will drain to the tank. If the right-hand end is connected to the pump, the piston will travel to the left. The speed of travel will depend on the volume of oil delivered by the pump in a unit of time.

The speed of piston rod travel may be adjusted by a throttle valve mounted in the pipeline through which oil is delivered to the cylinder (Fig. 57 *a* and *b*). This method of speed control is called "metering-in" control.

The speed of a piston and rod may also be controlled by a throttle valve governing the discharge of oil from the opposite end of the cylinder (Fig. 57 *c* and *d*). The amount of oil passing through the adjustable throttle valve, in a unit of time, will determine the piston speed. If the amount of oil delivered to the working end of the cylinder is too large, surplus oil is drained to the tank through a relief valve. This method is called "metering-out" speed control.

The speed of piston travel may also be adjusted by using a variable-displacement pump which can deliver different amounts of oil per unit of time.

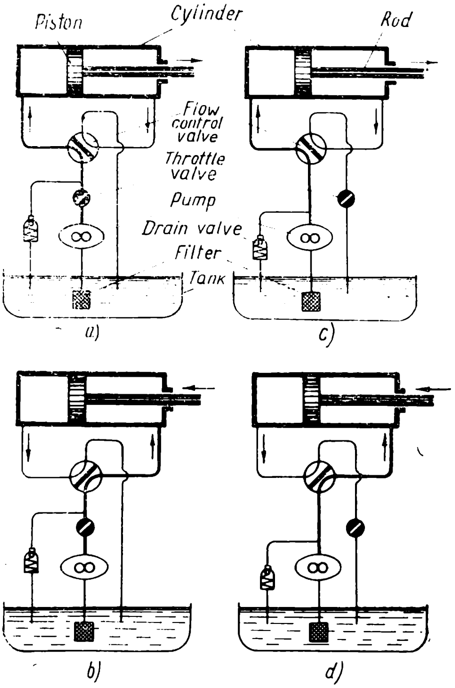


Fig. 57. Throttle type speed control circuits.

a and *c* — "metering-in" control, *b* and *d* — "metering-out" control.

§ 28. PUMPS

Pumps, applied in hydraulic drives of machine tools may be classified as *constant-displacement (non-adjustable)* and *variable-displacement (adjustable) pumps.* The displacement or delivery of a pump is the amount of oil it will deliver in litres per minute (l/min).

As to their principle of operation and design, pumps are classified as *gear* (Fig. 58 *a*), *vane* (Fig. 58 *b*), and *piston* types (Fig. 58 *c*).

At a given speed, *gear pumps* have a constant displacement. They are designed for operating pressures up to 25 atm (kg per sq cm). Gear pumps consist of the following principal parts: bodies accommodating two gears and two heads with bearings and packing glands. They operate by the suction of oil through pipeline *1* by the rotating gears. The oil is carried in the tooth spaces to the pipeline *2* where it is discharged.

Vane pumps consist of a cast iron housing *1* into which a hardened, ground and lapped steel cam ring with an elliptical bore is fitted. A rotor in this bore carries vanes located in slots of the rotor and held tightly against the elliptical surface of the cam ring. Vane pumps also have a constant displacement and are designed for working pressures up to 65 atm (kg per sq cm). In operation, the vanes draw oil through ports *2* and *3* and discharge it through ports *4* and *5*. The design illustrated in Fig. 56 *b* is the double-acting type.

Rotary piston pumps may be designed with either radially or axially arranged pistons. They may operate at pressures of 100 atm and more but their principle of operation is almost the same. In pump with axially arranged pistons, the latter are located in a body and reciprocate under the action of an inclined rotating disc. When the pistons are moving out of their bores in the body, they draw in oil; when the pistons are forced into the body bores, oil is discharged. The inclined disc may be set at various angles to change the piston stroke and the delivery of the pump.

§ 29. CYLINDERS, PISTONS, AND RODS

Cylinders, in conjunction with pistons and rods, are hydraulic actuating devices for straight-line motion. The force transmitted by a hydraulic cylinder and piston is proportional to its diameter and to the oil pressure.

If the cylinder is stationary, the piston rod is linked to the unit which is to be actuated. In some applications, the piston and rod are stationary and the cylinder is linked to the driven unit. Oil is delivered to the cylinder, in such cases, through the hollow piston rod.

The speed of piston rod travel is determined from the formula

$$v = \frac{40Q_a}{\pi (D^2 - d^2)} \text{ m per min,} \qquad (27)$$

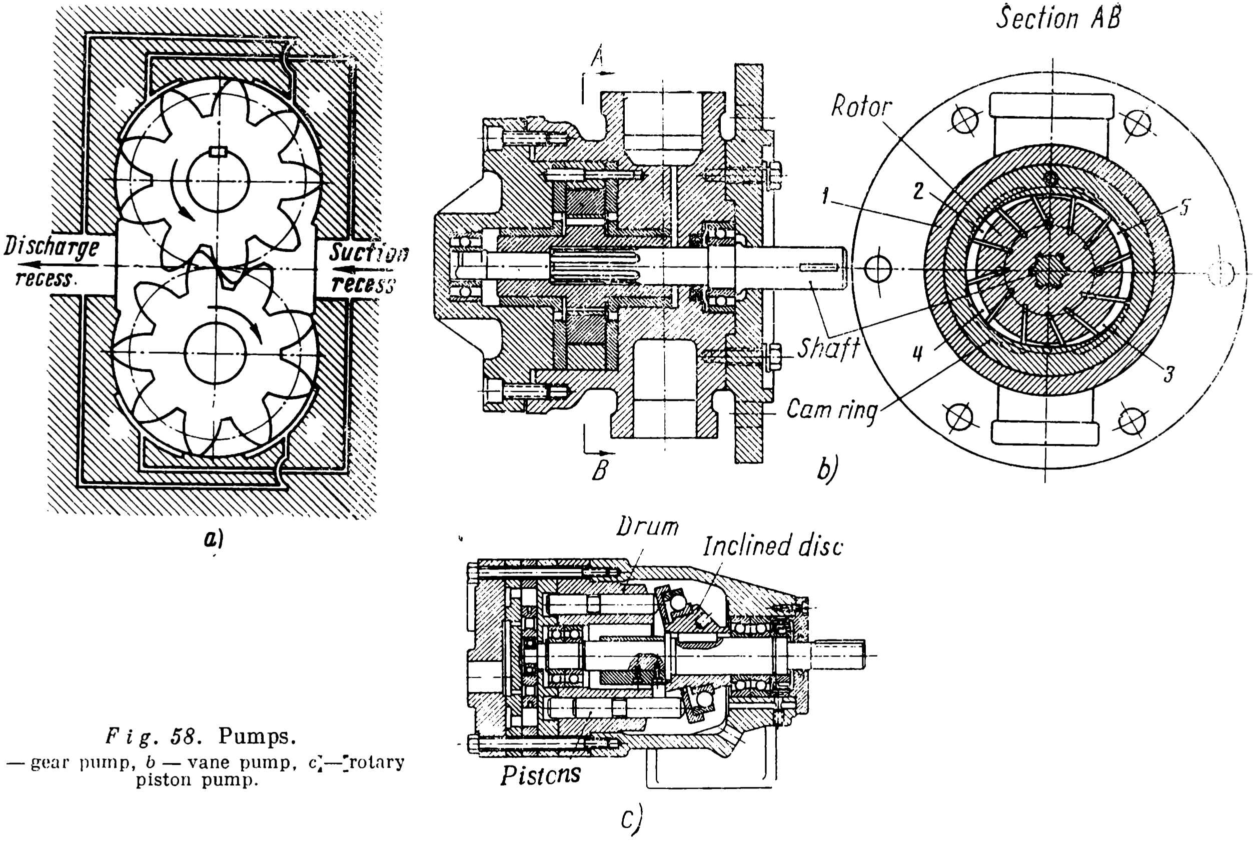


Fig. 58. Pumps.
a — gear pump, *b* — vane pump, *c* — rotary piston pump.

in which Q_a denotes the actual delivery of the pump in l per min;
$\pi = 3.14$;
D denotes the cylinder bore, in cm;
d denotes the rod diameter, in cm.

If no rod is arranged in the working end of the cylinder, then $d=0$ and the piston speed will be:

$$v = \frac{40Q_a}{\pi D^2} \text{ m per min.} \tag{28}$$

§ 30. HYDRAULIC DEVICES

Piston and rotary valve devices are used, as a rule, to control hydraulic drives by directing oil to the corresponding channels of a hydraulic system in accordance with the required sequence of movements of the machine tool units.

Piston valves are cylinders in which valve pistons are arranged. These pistons may be shifted, in various ways, manually, with camdogs, springs, solenoids or high pressure. In each definite position of the valve piston, its grooves are connected to different channels of the hydraulic system (Fig. 59).

Rotary valves are illustrated in the diagrams of Fig. 57.

Valves of various types, including throttle valves, relays and other devices, are used to adjust the pressure in the system.

Valves are employed to regulate the pressure in different sections of a hydraulic system. Safety valves protect a system against excess pressure and relief valves drain excess oil to the tank.

Reducing valves are employed when it is necessary to reduce the pressure in certain definite sections of a hydraulic system.

Pressure relays check the pressure and trip if the pressure in the system or in any section exceeds a certain permissible value. Time delay relays count off preset periods of time during which, for example, a certain control unit is not switched on.

Fig. 59 *a* represents a hydraulic system diagram for the feed drive of a toolslide from two vane pumps. The first is a high delivery, low-pressure pump and actuates rapid traverse movement (approach and withdrawal). For this purpose, oil is admitted to the front (rapid approach) or rear (rapid withdrawal) end of the cylinder through a safety valve when the main control valve piston is in its corresponding position.

The second pump, for a low delivery and high pressure, effects the feed motion and oil is delivered to the system through a screen filter, throttle valve, main control valve and to the front end of the cylinder.

When oil from the pumps is admitted to the front end of the cylinder, oil from the rear end escapes to the tank through the main control valve and a back pressure valve. The flow of oil and, conse-

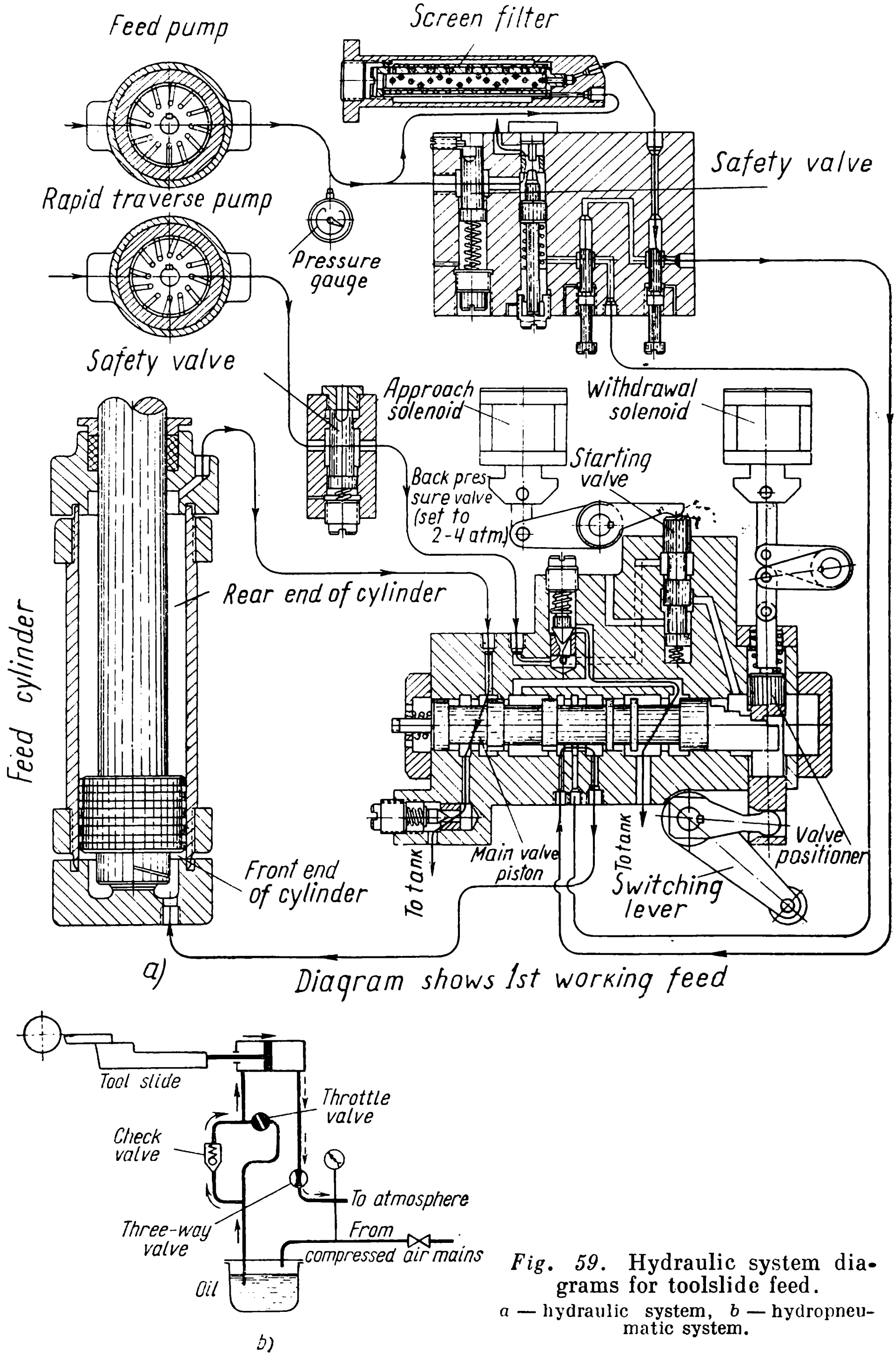


Fig. 59. **Hydraulic system diagrams for toolslide feed.**

a — hydraulic system, *b* — hydropneumatic system.

Trouble-Shooting Chart for Hydraulic Systems

Trouble	Cause	Remedy
Pump does not deliver oil	Shaft rotates in wrong direction	Reverse shaft rotation.
	Low oil level in tank.	Add oil to tank and check whether the end of the suction pipe is submerged.
	Oil intake pipe or suction filter is plugged	Clean filter and oil intake pipe.
Air gets into hydraulic system.	Air leaks into hydraulic system.	Stop leakage (leaks are found by noise of air forced out in operation).
	Insufficient pump shaft speed.	Check and increase the pump shaft speed.
	Oil is too thick and is not drawn up by the pump.	Fill the tank with thinner (lower viscosity) oil according to the instructions.
Pump does not develop pressure in the system.	Relief valve setting is not high enough.	Check, adjust the relief valve to the required pressure on the pressure gauge.
	Relief valve leaks.	Check the relief valve for leakage by blocking off oil delivery near the valve.
	Oil drains directly to the tank.	Check and clean the relief valve.
	Vanes are jammed in the rotor slots.	Check if oil is clean and eliminate jamming of vanes.
	Core passages in pump housing are damaged.	Replace the pump housing and check the setting of the relief valves with provision for impact loads.
	Intake line or filter is partially clogged, intake pipe has been restricted by crushing or denting.	Clean pipe and filter to admit oil freely to the pump (filter should be cleaned each shift by turning the handle).
	A small amount of air enters the pump through leaks in the joints.	Tighten up all joints (check by immersing in an oil bath, by pouring oil over the joint while listening for change in sound of operation).
Pump making noise.	Air enters through pump shaft packing.	Draw up packing glands (check as in preceding item).
	Vanes jam in rotor slots.	Check and clean oil of metal dust and of dirt.

(Continued)

Trouble	Cause	Remedy
	Chattering in relief valve.	Eliminate suction of air through pump intake or pump shaft packing.
	Pump head is not drawn up tightly or head gasket is faulty.	Draw up screws of head after replacing gasket.
	Foreign matter (paper or threads from waste) has got into the intake core passages.	Remove head and carefully clean out core passages in bronze discs and in housing.
	Air bubbles in intake line (oil has not settled properly).	Check whether return line ("To tank") is below oil level, separate intake pipe with a partition from the pipe for returning oil to the tank.
	High viscosity of oil (oil is too thick).	Use turbine oil L or pure spindle oil 3.
	Filter is clogged.	Clean filter.
Oil leakage.	Packing is worn.	Replace shaft packing.
	Oil leaks in piping joints.	Make joints tight.
	Packing of head is damaged.	Replace head packing as indicated above.

quently, the movement of the toolslides are controlled by the main control valve which is shifted and positioned as required by solenoids, a positioning device and a pilot lever. The latter is actuated by cam-dogs set up along the travel of the toolslide.

It is evident from the hydraulic systems described that they consist of pumps driven by motors, an oil tank or reservoir, filters, and a large number of hydraulic valves and other devices, all connected by pipelines. The following requirements are made to hydraulic systems: minimum oil leakage through packing and clearances, complete protection against the penetration of air into the system, and as constant as possible viscosity of the working fluid.

An elementary diagram of a hydro-pneumatic system is shown in Fig. 59 *b*. The design of this drive is based on throttling of oil on which compressed air acts and it operates from the plant compressed-air mains.

The oil is simply held in an oil tank into which compressed air is admitted from the mains at a pressure of 4 to 5 kg per sq cm. The pressure acting on the oil surface is the same as that in the compressed air mains. Consequently, oil will pass through the pipeline and check valve to the left end of the cylinder. This moves the piston to the right and withdraws the toolslide from the work. Air from the right end of the cylinder will be released to the atmosphere. When the toolslide is to be advanced to the work, a three-way valve is turned so that the compressed air is admitted to the right-hand end of the cylinder and not to the oil tank. The speed of the piston, however, will be restricted by the oil draining from the cylinder as it can pass only through the throttle valve. Thus, the speed of the piston (and toolslide) depends on the size of the slit in the throttle valve through which oil flows.

Troubles encountered in hydraulic systems and methods of their elimination are given in Table 1.

§ 31. HYDRAULIC TRACER-CONTROL UNITS

Hydraulic tracer-control units are extensively applied in automatic lathes to turn the contour of a workpiece to the profile of a template.

In principle, the operation of hydraulic tracer units resembles that of electric units (see § 26). They differ in that the tracer operates a hydraulic valve in a hydraulic system. Upon longitudinal feed of the carriage, obtained from an independent drive, the stylus follows the profile of the template and operates the valve that admits or exhausts oil under pressure on the opposite ends of a piston which transmits its motion to the toolslide. The neutral position of the control valve corresponds to tracing on a section of the template parallel to the spindle axis, i. e., when the cross feed should be disengaged.

The hydraulic tracer-control unit, model KCT-1, for universal engine lathes is shown schematically in Fig. 60.

This automatic unit enables the operating cycle for machining internal and external stepped and form surfaces to be completely automated.

The compound rest of an engine lathe is removed and the tracer-controlled slide is mounted in its place at an angle of 45° to the line of centres. The stylus of the hydraulic valve slides along the profile of a template or the contour of a prototype workpiece (or a three-dimensional model). The deflection of the stylus and valve is reproduced in the movements of the toolslide. Longitudinal feed is obtained from the lead screw and does not depend on the tracer system.

The tracer-control system operates as follows: oil from pump *1* is delivered to the rod end of cylinder *2*. This end is connected through the hollow piston and rod with the other end of this cylinder and also with the control valve piston *3*. The valve housing is fastened rigidly to the slide while a spring holds the valve piston with the stylus against the template profile. An annular recess is provided between the valve piston and housing. Upon downward movement of the valve piston, oil escape from the piston end of the cylinder is cut off and an equal pressure is set up in both ends of the cylinder. Since the cross-sectional area of the lower end of this cylinder is twice that of the upper (rod) end, the slide will travel toward the work. Pressure on the stylus opens the recess and releases oil from the piston end of the cylinder to the tank. In this case, the pressure in the rod end will exceed the pressure in the piston end of the cylinder and the slide will travel away from the work. If the recess is opened only slightly and the resistance offered to oil escaping from the piston end of the cylinder brings the pressure in this end to one half of the pressure in the rod end, the slide will be in a balanced condition.

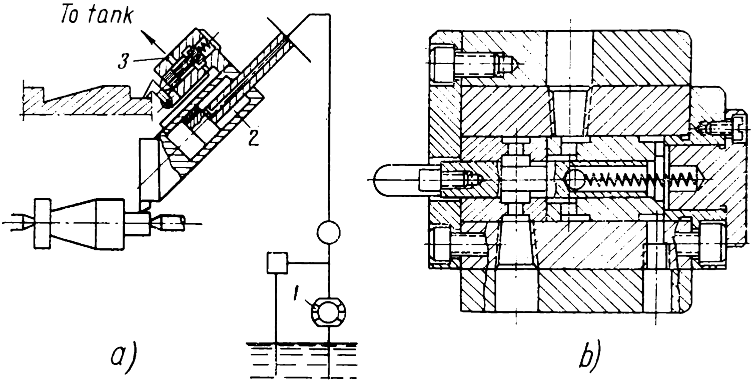


Fig. 60. Hydraulic tracer-control unit, model KCT-1.
a — hydraulic system diagram, *b* — hydraulic valve.

Two-coordinate hydraulic tracer-controlled systems, in which longitudinal feed is dependent on cross feed, are usually used in automatic lathes at the present time. If the form of the contour being turned requires an increase in the depth of cut at any particular point, i.e., increased infeed of the cross slide, the longitudinal feed will be automatically reduced. When, on the other hand, the depth of cut is reduced, the longitudinal feed is correspondingly increased.

A diagram of a hydraulic system of this type, designed for application on single-spindle automatics and semi-automatics, is illustrated in Fig. 61.

From the pump, oil is delivered simultaneously through the tracer valve, controlled by the form of the template, into one of the ends of the cross feed cylinder and into the right-hand end of the longitudinal feed cylinder.

If the curve on the template begins to deviate away from the stylus, the cross slide, reproducing the movement of the stylus, will be fed into the work and oil from the opposite end of the cross feed cylinder will drain through a throttle valve to the tank. Oil flow in the ends of the cross feed cylinder will be reversed when the curve rises on the template.

In places where the template profile is a straight line parallel to the workpiece axis, the tracer valve is held in a neutral position and oil does not enter either end of the cross feed cylinder.

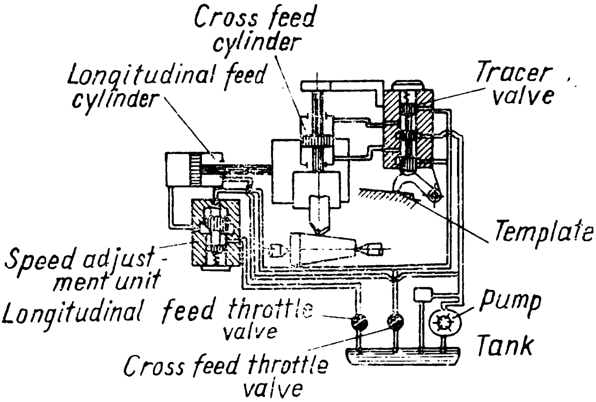

Cross feed cylinder
Longitudinal feed cylinder
Tracer valve
Template
Speed adjustment unit
Longitudinal feed throttle valve
Pump
Tank
Cross feed throttle valve

Fig. 61. Hydraulic tracer-controlled system.

Oil from the left-hand end of the longitudinal feed cylinder passes through the speed adjustment unit and the throttle valve to the oil tank. An increase in cross feed will increase the pressure before the throttle valve in the drain of the cross feed cylinder. This will reduce the flow through the speed adjustment unit and, consequently, the longitudinal feed.

CHAPTER IV

GRAPHICAL DIAGRAMS FOR AUTOMATICS AND SEMI-AUTOMATICS

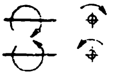
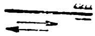
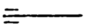
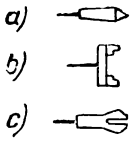
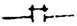
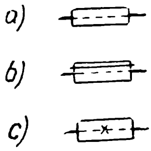
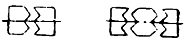
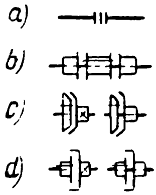
§ 32. KINEMATIC OR GEARING DIAGRAMS

Kinematic diagrams are conventional graphical representations of the linkages between the elements of the drive and controls of a given machine tool.

As shown in many of the preceding illustrations, transmissions and mechanisms are denoted by simple graphical symbols which resemble, to some extent, the actual devices they represent. This enables the symbols employed in kinematic diagrams to be easily memorised. A kinematic diagram will clearly illustrate all the motions of the machine tool.

Table 2

Graphical Symbols Used in Gearing Diagrams

Description	Symbol
Shaft rotation	
Rigidly fixed rod, pin, etc.	
Fixed guiding element of reciprocating rod	
Shaft running in plain or antifriction bearings	
Spindle noses: *a* — centre type *b* — chuck type *c* — bar type	
Coupling between two shafts	
Parts mounted on shafts: *a* — freely mounted *b* — sliding on feather *c* — fixed on key	
Jaw clutches	
Friction clutches: *a* — general symbol (type not indicated) *b* — twin type (general symbol) *c* — cone *d* — disc	

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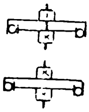
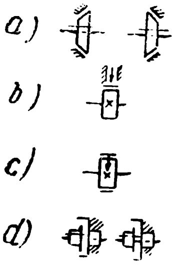
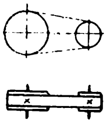
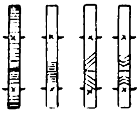
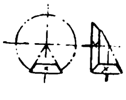
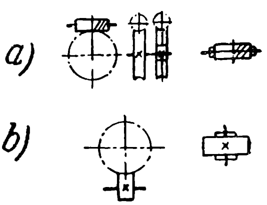
Description	Symbol
Overrunning clutches	
Brakes: *a* — cone *b* — shoe *c* — band *d* — disc	
Flat belt drive	
Toothed gearing between parallel shafts with spur, parallel helical, and herringbone gears	
Toothed gearing between intersecting shafts — bevel gearing	
Toothed gearing between crossed shafts: *a* — worm gearing *b* — crossed helical gearing	

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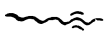
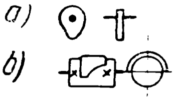
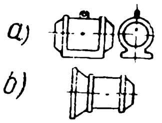
Description	Symbol
Nut on power screw	
Cams: *a* — plate cam *b* — cylinder cam	
Electric motors: *a* — on feet *b* — flange-mounted	

Such diagrams serve as a basis for establishing the kinematic relations required to set up a machine tool. They enable change gears to be selected to obtain a certain spindle or camshaft speed or they enable the required gear shifts to be determined for this purpose, etc.

Data indicated in a kinematic or gearing diagram enable the machine tool to be set up kinematically. The number of teeth, module, and helix angle of toothed gears are given, as well as the pitch and hand of the thread on screws. The more important elements of the machine are provided with the corresponding inscriptions, such as: spindle, camshaft, engaging lever, brake, etc.

The gearing diagram is usually inscribed into the general outline of the machine and the actual locations of the various units and mechanisms are retained in the diagram where this is feasible.

Certain conventionalities are inevitable in making gearing diagrams of machine tools since the diagrams are necessarily two-dimensional and the elements of the machine are arranged in three-dimensional space.

Shafts, shown vertically in the diagram, may actually have a horizontal position but perpendicular to longitudinal horizontal shafts, certain shafts are drawn bent when this is necessary, etc.

As a rule, service manuals, furnished with each machine tool, have a gearing diagram.

The principal symbols, encountered in gearing diagrams, are given in Table 2.

Gearing diagrams, which are not very complex, may be represented conventionally by an isometric drawing.

The gearing diagram of the main drive in a multiple-spindle automatic is shown in Fig. 62.

Power is transmitted from the electric motor (7 kw, 1,470 rpm) through the belt drive (with pulleys, $d_1=240$ and $d_2=180$), a pair of change gears (Z_1 and Z_2) and constantly meshing gears (Z_3 and Z_4) to the central shaft on which the central gear Z_5 is mounted. Gears Z_6, mounted on the spindles, mesh with the central gear Z_5. It is evident from Fig. 62 that all the spindles rotate in the same direction and at the same speed.

An isometric gearing diagram of a Swiss-type automatic screw machine is illustrated in Fig. 63.

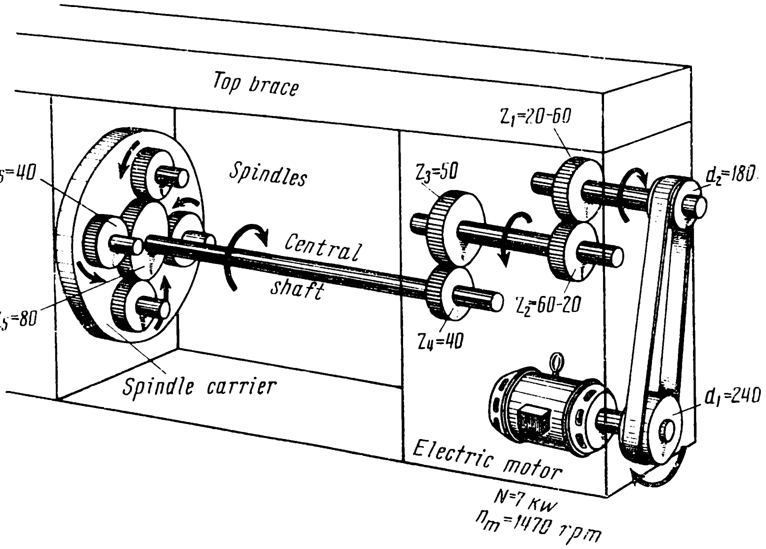


Fig. 62. Isometric gearing diagram of the main drive in a multiple-spindle automatic.

Rotation is transmitted from the electric motor through change pulleys and a belt drive to an intermediate shaft. A wide pulley, mounted on this shaft, accommodates a flat belt which drives the spindle. A belt tightening pulley provides for the proper tension of the belt. This pulley also transmits rotation through several other elements to the camshaft which carries the cams for controlling the movements of the operative units.

Formulas given in Fig. 63 enable the spindle and camshaft speeds of model 116a to be determined.

The gearing diagram and principal setting-up formulas for the model 1136 automatic screw machine are given in Fig. 64.

As a rule, one workpiece is produced per revolution of the camshaft. Consequently, the cycle time or (for automatics only) the time per

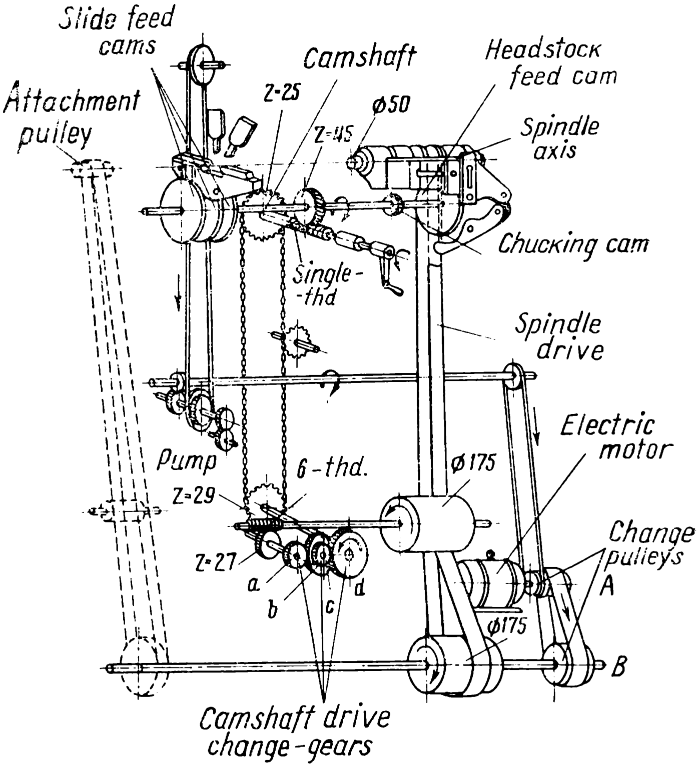


Fig. 63. Isometric gearing diagram of Swiss-type automatic screw machines, models 116a and 1110a.

Setup formula for model 116a:

$$n_s = n_m \frac{A}{B} \times \frac{175}{50} \text{ rpm};$$

$$n_{cs} = n_m \frac{A}{B} \times \frac{175}{175} \times \frac{6}{27} \times \frac{a}{b} \times \frac{c}{d} \times \frac{29}{25} \times \frac{1}{45} \text{ rpm}$$

in which n_s, n_m and n_{cs} are the spindle, motor and camshaft speeds, respectively. One revolution of the camshaft corresponds to:

$$\frac{45}{1} \times \frac{25}{29} \times \frac{d}{c} \times \frac{b}{a} \times \frac{27}{6} \times \frac{175}{50} \text{ spindle revolutions, i.e., } \frac{a}{b} \times \frac{c}{d} = \frac{A}{n_{cycle}}$$

$$\text{in which } A = \frac{45}{1} \times \frac{25}{29} \times \frac{27}{6} \times \frac{175}{50};$$

n_{cycle} is the number of spindle revolutions to make one workpiece;
a, b, c, and d are the number of teeth on the change gears;
A and B are the diameters of the change pulleys.

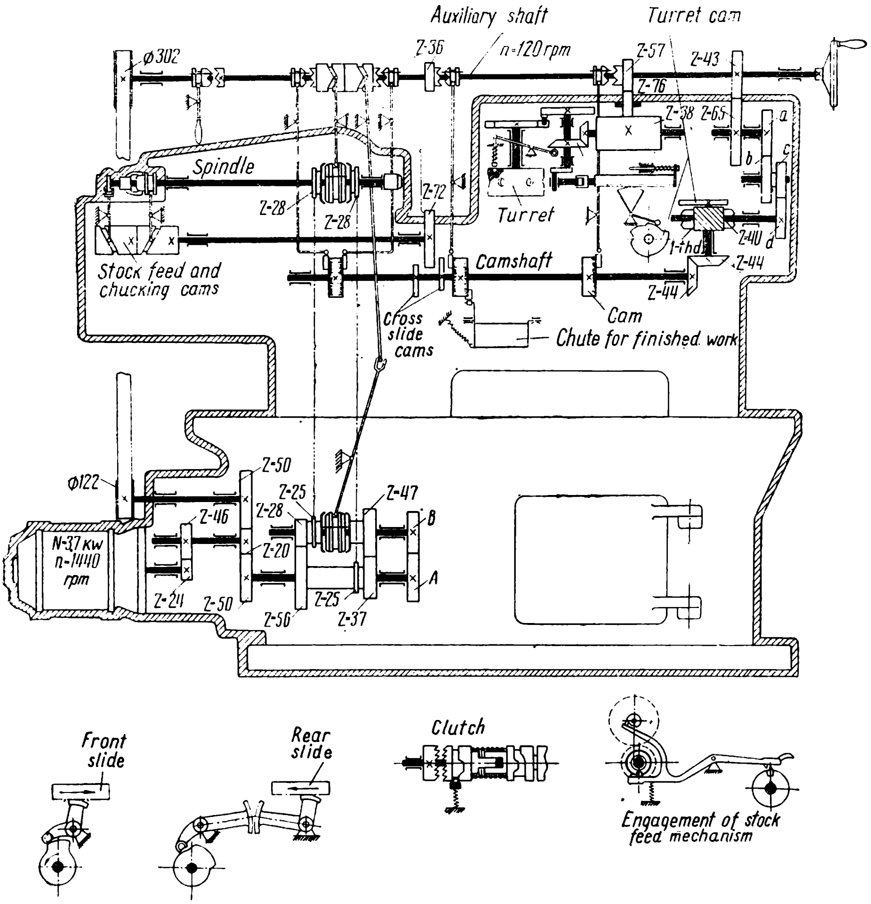


Fig. 64. Gearing diagram of the automatic screw machine, model 1136.

Spindle speeds, rpm:

$$n_s = 1{,}440\,\frac{24}{46}\times\frac{20}{50}\times\frac{A}{B}\times\frac{28}{56}\times\frac{25}{28}\ \text{rpm (forward rotation)};$$

$$n_s = 1{,}440\,\frac{24}{46}\times\frac{20}{50}\times\frac{A}{B}\times\frac{25}{28}\ \text{rpm (reverse rotation)};$$

$$n_s = 1{,}440\,\frac{24}{46}\times\frac{20}{50}\times\frac{A}{B}\times\frac{47}{37}\times\frac{25}{28}\ \text{rpm (forward rotation)};$$

$$n_s = 1{,}440\,\frac{24}{46}\times\frac{20}{50}\times\frac{A}{B}\times\frac{47}{37}\times\frac{56}{28}\times\frac{25}{28}\ \text{rpm (reverse rotation)}.$$

Speed of auxiliary shaft, rpm: $n_{as} = 1{,}440\,\frac{24}{46}\times\frac{20}{50}\times\frac{122}{302} \approx 120$ rpm.

Setup formula for camshaft speed:

$$n_{cs} = n_{as}\,\frac{43}{65}\times\frac{a}{b}\times\frac{c}{d}\times\frac{1}{40} \approx 2\,\frac{a}{b}\times\frac{c}{d}\ \text{rpm}.$$

Cycle time:

$$T_c = \frac{1}{n_{cs}} = \frac{1}{2}\cdot\times\frac{b}{a}\times\frac{d}{c}\ \text{minutes}.$$

piece in minutes equals the reciprocal of the camshaft speed in rpm. The following formulas serve for determining the cycle time in minutes and in seconds:

$$T_c = \frac{1}{n_{cs}} \text{min and } T'_c = \frac{60}{n_{cs}} \text{ sec.}$$

§ 33. ELECTRICAL CIRCUIT DIAGRAMS

Electrical circuit diagrams serve to depict the interrelations between all of the elements in the electric drive and controls of a machine tool by means of conventional symbols.

Fig. 65 illustrates an electrical line (circuit) diagram for the 6-spindle automatic bar lathe. This automatic has two electric motors: *1M* — main drive motor and *2M* — coolant pump motor.

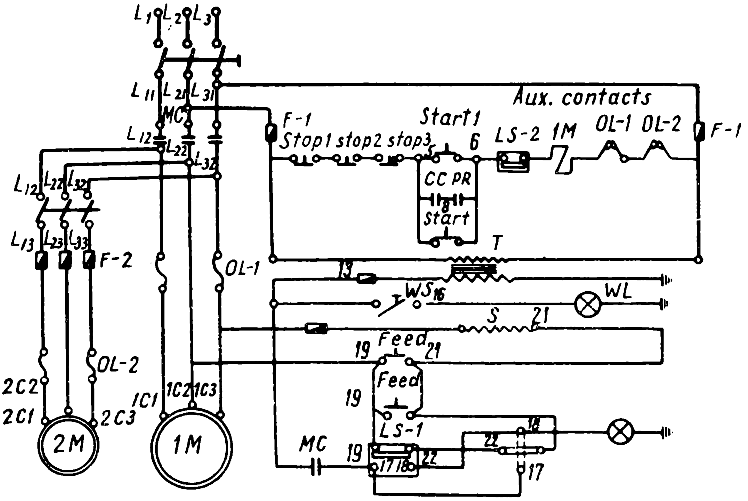


Fig. 65. Electrical circuit diagram for the 6-spindle automatic bar lathe, model 1261M.

Both motors, solenoid *S* and the electrical control devices are included in a 380 V circuit while the work light *WL* and the signal lamp *SL* are in a 36 V circuit supplied from a 380/36 V step-down transformer *T*.

Both motors are switched on or off (across-the-line) by the magnetic starter *M*. The coolant pump motor may be additionally controlled by the rotary switch *RS*. The work light *WL* is turned on with the switch *WS*.

All electrical equipment is controlled from a central push-button station located on the top brace.

Thermal-type overload relays, *OL-1* and *OL-2* are provided to protect the motors against overloads, as well as fuses *F* for protection against short circuits. Pressing the "start" button will energise the coil of the magnetic starter *M*. This closes the starter and, consequently, the main contacts *MC* to switch on the motor *1M*. The auxiliary control contacts *CC* of the starter also close, but the "holding" circuit of the magnetic starter is not yet closed and the "start" button must be held down. After the establishment of a normal pressure in the lubricating system, the contacts of the pressure control relay *PR* are closed to close the "holding" circuit, mentioned above, and the push button may then be released without switching off the drive motor.

To prevent an accident that might occur if the automatic is started while it is being restocked, a special lever actuates the limit switch *LS-2* and opens the motor control circuit. Before pressing the "start" button it is necessary to close switch *LS-2*. If limit switch *LS-1* is actuated, the solenoid *S* is deenergised and signal lamp *SL* is lit up to indicate that the camshaft will be disengaged at the end of the present operating cycle because the bar stock has been used up in one of the spindles. The corresponding spindle should be restocked.

§ 34. HYDRAULIC SYSTEM DIAGRAMS

The movements of elements in a machine tool, equipped with a hydraulic drive, are shown in a hydraulic system diagram. Fig. 66 shows a hydraulic system diagram for the slide drive of an automatic lathe. The elements of the system are shown in the "rapid approach" position. From the pump, oil is delivered through the main control valve to the left end of the cylinder. The valve is shifted to this position by a pushing-type solenoid after compressing the valve piston spring. In this position, recesses *2* and *3* of the main valve are connected together. Oil from the right end of the cylinder drains freely through recesses *4* and *5* back to the tank. The piston, linked to the slide, is unrestricted and advances the slide rapidly to the work.

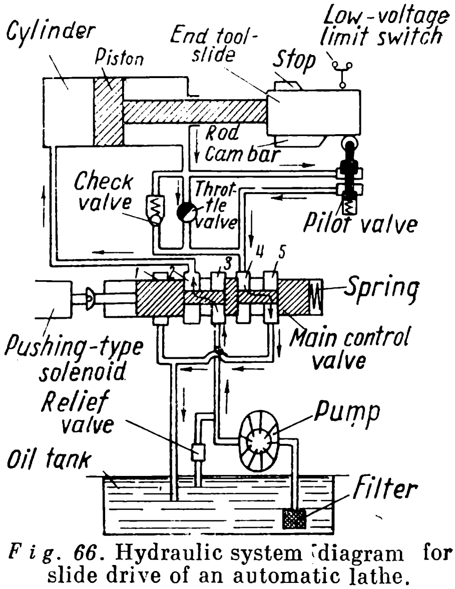


Fig. 66. Hydraulic system diagram for slide drive of an automatic lathe.

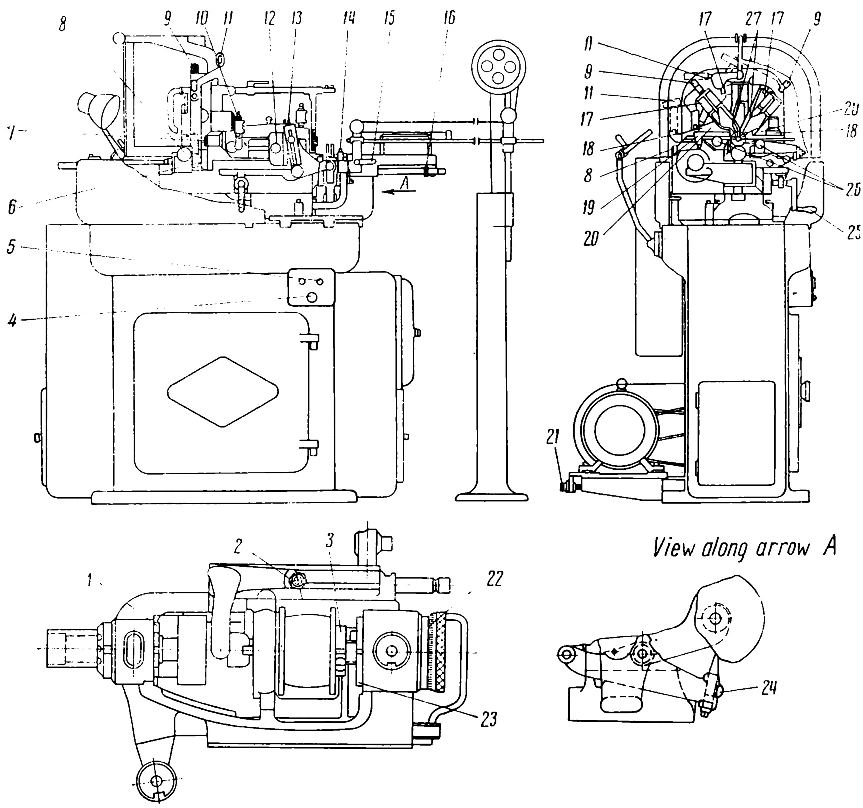


Fig. 67. Control diagram of the Swiss-type automatic screw machine, model 1A10П.

When the cam bar of the slide, in further movement, depresses the pilot valve, its recesses are blocked off. After this, oil from the right end of the cylinder can pass only through the throttle valve and the speed of piston travel is sharply reduced.

The rate of working (slow) feed of the slide may be set by setting the throttle valve. Part of the oil delivered by the pump will be discharged through a relief valve back to the tank.

At the end of the working feed, the slide will trip a low-voltage switch which deenergises the solenoid. The spring will now shift the valve piston to its left-hand position, connecting recess *1* to *2* and recess *3* to *4*. At this, the pump will deliver oil to the right end of the cylinder through recesses *3* and *4* and the check valve (recess *5* is closed). Oil from the left end of the cylinder will pass freely through recesses *1* and *2* back to the tank. The piston and slide will travel in the reverse direction at the same speed as in the rapid approach.

§ 35. CONTROL DIAGRAMS

Control diagrams are employed to explain the purpose of the various control devices and the control system of a machine tool. Such a diagram is usually a general view of the machine tool on which all of the principal units, setting-up elements and control devices have been drawn. Control diagrams often indicate the places of adjustment as well.

The control diagram of the model 1A10П Swiss-type automatic screw machine is given in Fig. 67. The numbers in the diagram denote the following elements, control devices and places of adjustment:

1—nut for adjusting the front spindle bearing, *2*—pin to adjust the clamping force of the collet (to prevent the collet jaws from contacting the clutch face during clamping, the lock must be released and the eccentric pin *2* turned so that a *4* mm clearance is provided between the clutch and jaw tips), *3*—collet clamping adjustment (for adjusting the collet jaws in reference to the clutch), *4*—work light switch, *5*—"start" and "stop" handle, *6*—rocker-arm stop adjustment, *7*—stationary work-rest adjustment, *8*—screws for cross adjustment of the rocker-arm slides, *9*—screws for cross adjustment of the tool-frame slides, *10*—screws for longitudinal adjustment of the tool-frame slides, *11*—nut for setting arm lengths of the tool-frame slide levers, *12*—screw for clamping the headstock bar, *13*—screw for setting and fine adjustment of the headstock, *14*—adjustment of stop for extreme front or rear position of the headstock. This enables the setting for the length of simple parts to be made without changing the cam, *15*—lever for clamping the loading device bracket, *16*—adjustment of the spring for the return stroke of the headstock, *17*—screws for adjusting the slides in height in reference to the spindle axis, *18*—screws for adjusting the rocker-arm toolholders in height in reference to the work axis, *19*—adjustment of rocker-arm swing in reference to the cams (enables the tools to have two different positions), *20*—clamping of the rocker-arm tools in their toolholders, *21*—screw for tensioning the belt, *22*—nut for adjusting the rear bearings; excess clearance is eliminated by releasing the stop screw, rotating the graduated nut *23*, having left-hand thread, until resistance is felt and then retightening the stop screw, *24*—screw for locking the pin feed screw, *25*—crank handle for rotating the camshaft (for manual operation the handle is pushed forward into engagement; for power operation it is pulled back out of engagement), *26*—screws for longitudinal adjustment of the rocker-arm slides, and *27*—screw for clamping cutting tools.

CHAPTER V

CYCLE AUTOMATION SYSTEMS

§ 36. CYCLOGRAMS

The adopted system of automation for any machine tool must provide for a proper sequence of the cycle elements and a duration of sufficient accuracy for each element.

A cyclogram of machine tool operation serves to check the cycle setup and its various elements. A cyclogram is a diagram showing all movements of the machine units in the sequence and with the durations that must be strictly conformed with in the actual cycle.

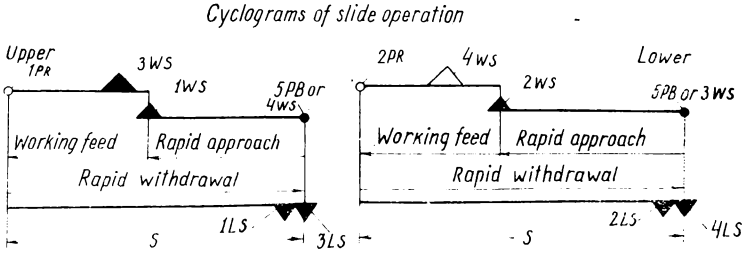


Fig. 68. Cyclograms of slide operation for a hydraulic multiple-tool semi-automatic lathe (control on a travel basis). The symbol denotes dogs tripping the way and limit switches. Dog 3WS (4WS) is installed only if the slides are to operate consecutively and is mounted on the slide which first begins operation.

The different machining operations and auxiliary movements of all units and mechanisms are established either by their travel (Fig. 68) or by the angle of rotation of the camshaft corresponding to the given travel (Fig. 69).

In hydraulic, electric, or combination control systems, the cycle is controlled along the line of travel of the operative units which transmit the required work signals. The cyclograms for such machine tools are more expediently plotted on a travel basis (see Fig. 68).

These cyclograms indicate the required locations of cams, dogs, and stops which actuate the control devices to change over from rapid approach to working feed, from working feed to rapid withdrawal, etc.

In mechanically-controlled systems with camshafts, the cyclogram is drawn by indicating all units in motion during the cycle along a vertical side of the diagram and divisions of 360° along a horizontal side or vice versa. It is then possible to indicate during which angle of camshaft rotation each unit is in motion or at rest. As shown in Fig. 69, rest is denoted by a horizontal line, while a rising or

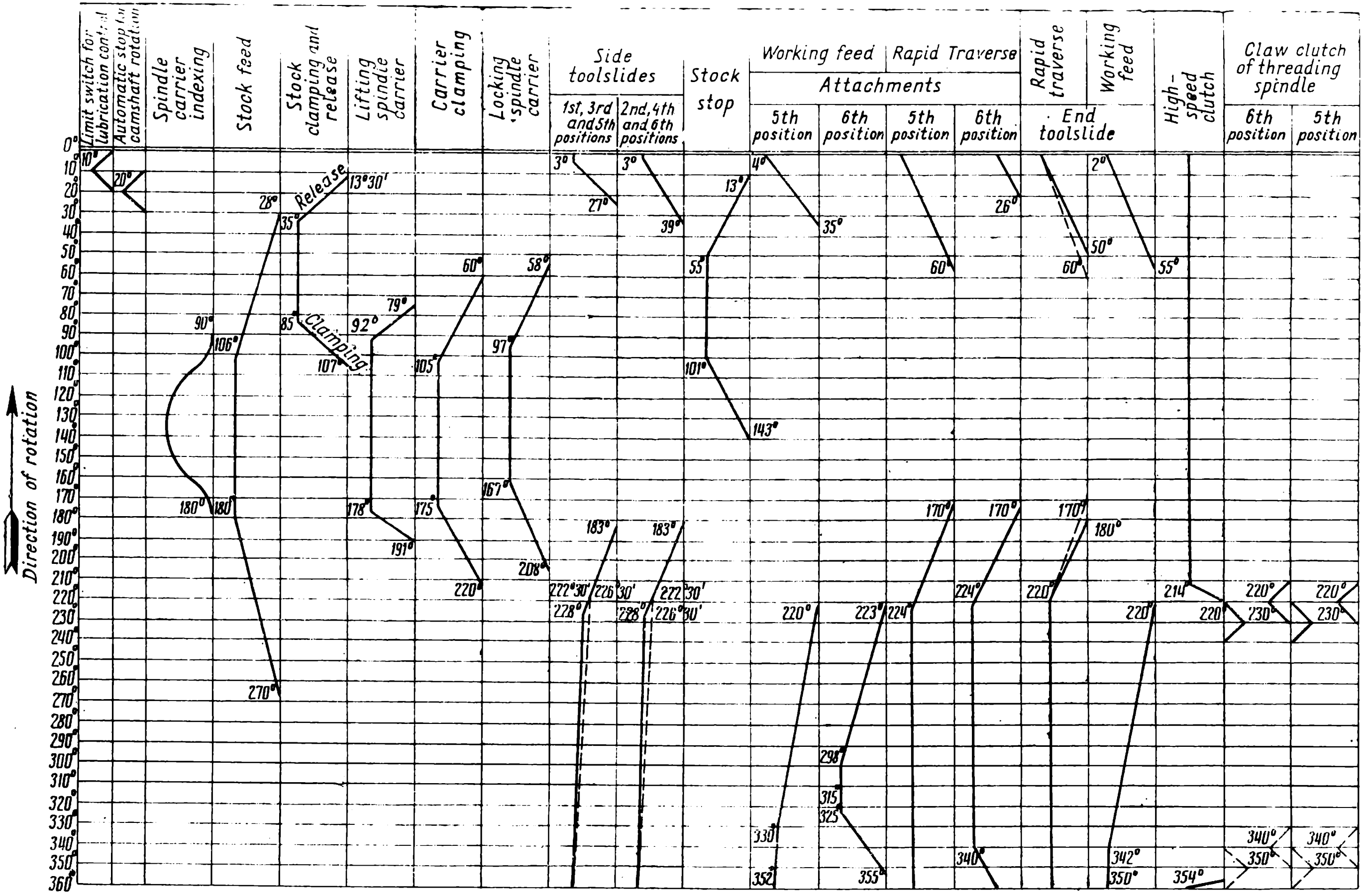


Fig. 69. Cyclogram of multiple-spindle automatic bar machine operation (control on the basis of camshaft rotation angle).

falling line denotes movement. Thus, cam mechanisms for driving and controlling each unit may be laid out, manufactured, and installed in accordance with data determined from the cyclogram.

Cyclograms may be of the circular or developed types. The latter are more easily read (see Fig. 69).

§ 37. CYCLE AUTOMATION SYSTEM CLASSIFICATION

Automatic control of machine tools should ensure a strict sequence of engagements, disengagements and adjustments of the magnitude and speed of travel of the various units or the duration of their movement. In addition, the automation system should enable a machine tool to be quickly set up to suit the size, form and material of the workpiece, and the adopted speeds and feeds. The system should also allow the whole cycle to be run through manually in separate elements, when setting up the machine tool.

If any operation is not performed, due to some failure in the mechanism, the machine tool should stop automatically.

Machine tool cycle automation systems may be classified into the following seven types:

1. Automatics and semi-automatics in which each motion or group of movements is actuated by an independent kinematic train while their sequence is established by the corresponding position of the cam on the camshaft in accordance with the required duration of the motion, i. e., in time (see Figs. 63 and 64).

One disadvantage of such automatics and semi-automatics is that the operating cycle will continue even if some specific operation has not been performed for some reason or other.

2. Automatics and semi-automatics in which control is arranged so that each unit may begin its travel only after a preceding unit has traveled a definite distance in accordance with the established cycle.

All control and switching over movements and all machining operations of a unit are arranged along its line of travel (Fig. 70 *a* and *c*).

3. Automatics and semi-automatics in which movements are actuated chiefly by electric or hydraulic means while their control is set up in a distributing device not linked to the drives of the working motions (Fig. 70 *b*). These automatics possess the same disadvantages as those of the first group.

4. Automatics and semi-automatics in which the travel of each unit may be engaged only after automatic inspection has proved that the quality of the preceding operation is satisfactory.

Control in such machine tools is associated with a device which gauges the size of the machined surface. If the gauged dimension is near to the allowable limit, the cutting tool will be automatically reset or the machine will be stopped. Defective workpieces ("rejects") may be eliminated in the operation of machine tools based on this principle.

5. Automatics and semi-automatics with a tracer-control system in which all working movements are prescribed by a master gauge or template.

This system has an electric (see Fig. 55) or hydraulic (see Figs. 60 and 61) tracer stylus. Tracer-controlled automation is one of the most effective systems for machine tools employed in medium- and small-lot production. At the present time, it has been found expedient, in many cases, for mass production as well.

6. Automatics and semi-automatics controlled by punched tapes, punched cards, magnetic tapes or by a drum. Methods of punched tape and punched card control are illustrated in Fig. 71. A drum periodically moves the punched tape. Control pins that coincide with the holes in the tape drop into these holes to engage definite units and mechanisms.

Electric, hydraulic and pneumatic systems operate in the same manner; the corresponding electrical contacts are closed in the first

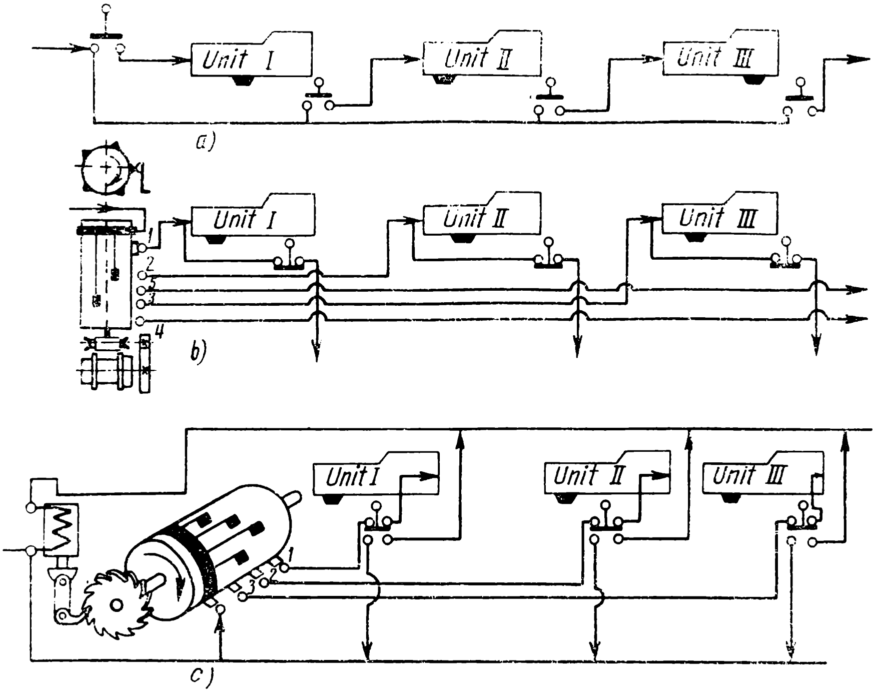


Fig. 70. Electrical control systems.
a—decentralised in-travel control system, b—centralised time-sequence control system, c—centralised in-travel control system.

case and, in the second and third cases, oil or compressed air is admitted to the corresponding cylinders.

A schematic diagram of a magnetic tape control system for a lathe carriage *9* is shown in Fig. 72. The arrangement is controlled from the magnetic tape *1* through the reproducing head *2*, control channels *3* and the servo system, consisting of two selsyns *6* and *11*, electronic device *4* and amplifiers *5*. Longitudinal feed of the saddle *8* is powered by the electric motor *7*, the cross slide *9* is traversed by motor *10*, while the main drive and auxiliary devices are powered by motor *12*.

7. Machine tools in which the control arrangemnts are located outside of the machine (remote control) and are employed to change the speeds and direction of motions of the units and mechanisms. This control method is effected by either electromechanical or electrohydraulic means and is widely used in heavy-duty engine lathes.

§ 38. MECHANICAL CONTROL SYSTEMS

Mechanical control systems are typified by a rigid linkage between the working and auxiliary operations. The two following mechanical systems are employed:

1. Control system comprising a single camshaft which provides for all working and auxiliary motions. This is the simplest arrangement and is further classified into the two following types:

a) Systems in which the camshaft speed is set up and remains constant during the complete cycle (see Fig. 63). All auxiliary (handling) motions for various setups are performed on a constant angle of rotation of the camshaft. This system may be applied only for automatic machine tools with a short machining cycle (up to about 20 sec).

b) Systems in which the camshaft speed is set up for the working movements. Auxiliary movements are performed at a high constant speed of the camshaft that is independent of the setup (Fig. 73). The mass of the camshaft with the cam drums and discs is comparatively large and large torques which lead to impact loads appear at the moment when the camshaft switches over from high to low speed.

This last system is the one most extensively used for multiple-spindle automatics and semi-automatics.

2. Control system comprising a main and an auxiliary camshaft (see Fig. 64). The machining cycle is completed in one revolution of the main crankshaft which runs at a set-up speed. Cams on the main camshaft actuate working movements and also give work signals for the performance of auxiliary operations. These work signals link the operative devices for auxiliary movements to the auxiliary camshaft.

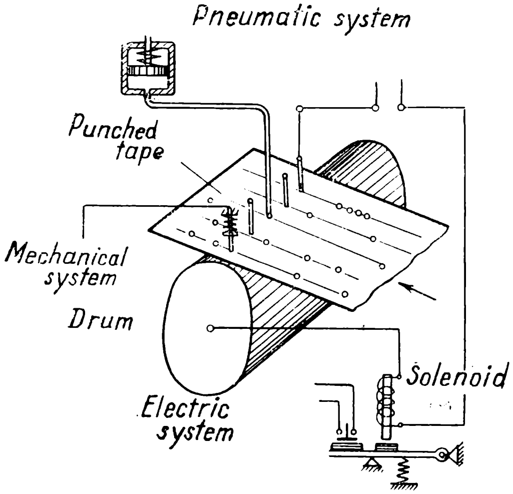


Fig. 71. Punched-tape systems of machine tool control.

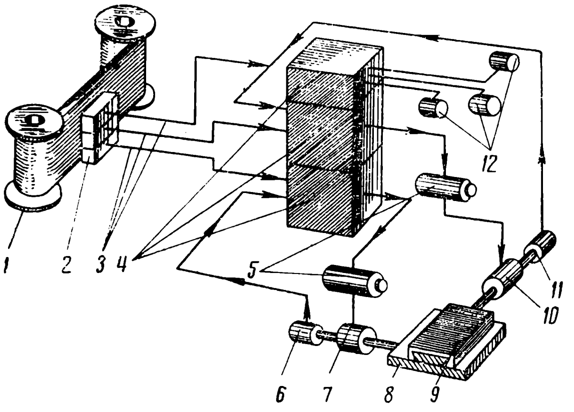


Fig. 72. Programme-controlled system of lathe operation.

1 — magnetic tape, *2* — reproducing head, *3* — control channels, *4* — electronic device, *5* — amplifiers, *6* and *11* — selsyns, *7* — longitudinal feed motor, *8* and *9* — cross slide driven by motor *10*, *12* — main drive motor and motors of auxiliary drives (pumps, etc.).

Systems with main and auxiliary camshafts are more complex than the preceding systems due to the large number of transmission elements and levers. They are employed, however, in automatic screw machines and vertical multiple-spindle semi-automatic chucking machines.

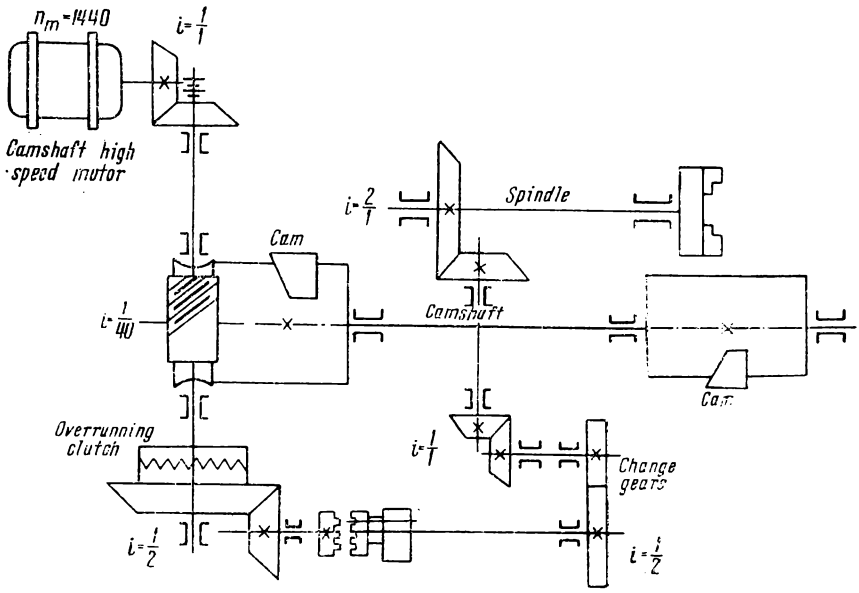


Fig. 73. Schematic diagram of an automatic lathe with a single camshaft.

§ 39. HYDRAULIC, PNEUMATIC, ELECTRIC, AND COMBINED SYSTEMS

Hydraulic, pneumatic, electric, and combined systems of cycle automation are distinguished for their high versatility and wide ranges of adjustment. They may be quickly and conveniently set up for various work.

At the present time, hydraulic drives are among the most easily applied systems of cycle automation and are usually employed in conjunction with hydroelectric controls.

A hydraulic system consists of pumps delivering oil under pressure to operative cylinders and serves mainly to obtain reciprocating motions. Control devices set up the magnitude and directions of travel of various units, as well as the sequence of their operation within the working cycle of the automatic.

One pump is usually sufficient for small machine tools, while two pumps are customary for larger sizes. In the latter case, one pump with a low delivery at a high pressure provides for the working travel and the second pump with a high delivery at a low pressure actuates all auxiliary rapid traverse movements.

Hydraulic drives enable the time lost in changing over from one job to another to be substantially reduced and thus allow hydraulic automatics and semi-automatics to be expediently employed for short runs with small lots.

As distinguished from mechanical systems, hydraulic drives do not have rigid transmission ratios between the driven and driving elements.

When a hydraulic drive is applied, the design of various auxiliary devices, loading fixtures, magazines, switching over and locking devices is often simpler than in mechanical systems; clamping devices are usually smaller in size.

Hydraulic and electric automation systems may be classified into three groups:

1. Decentralised in-travel control systems (see Fig. 70 *a*) in which the first work signal starts the operation of the system and each operative unit, in its line of travel, engages the next unit. This system is decentralised since it has several control devices located in different places and enables the machine tool to be set up quickly enough to the required cycle. It is difficult, however, to proceed with the cycle after unforeseen stops and the system is thus applicable only for simple cycles.

2. Centralised control systems (see Fig. 70 *b*) having a rotary control device (time-sequence control) which is set up to the cycle time. This system is centrally controlled and is similar to mechanical systems with a single camshaft. The cams mounted on the control device are of standard form. This facilitates setting up and any setup may be easily repeated subsequently. Due to the non-rigid kinematic linkages in hydraulic and electrical systems, this automation method will require a large number of safety (or interlocking) devices for reliable operation. At the present time, centralised time-sequence control systems are seldom used.

3. Centralised in-travel control systems (see Fig. 70 *c*) with a control device which periodically revolves through the required angle. This control system is usually equipped with a master switch which enables the cycle elements, cycle time and machining conditions to be easily set up or changed over for other jobs. The application of such a system is convenient when separate elements of the cycle require longer machining times since excessively slow rotation of the control drum is not necessary. After all motions have been completed in a certain phase of the cycle, a work signal is given to energise the solenoid which indexes the control device and then the motions begin in the next phase of the cycle.

§ 40. PROGRAMME-CONTROLLED SYSTEMS

An example of a programme-controlled machine tool is the automatic production lathe, model 1C62 (Fig. 74). It is manufactured as a modification of the basic model 1K62 and is designed for turning shafts between centres.

The lathe operates on a fully automatic cycle and is equipped with a loading and unloading attachment which is applicable both for individual work of the lathe, and for operation if the lathe is built into an automatic transfer machine.

Automatic controls are effected by electric master switches.

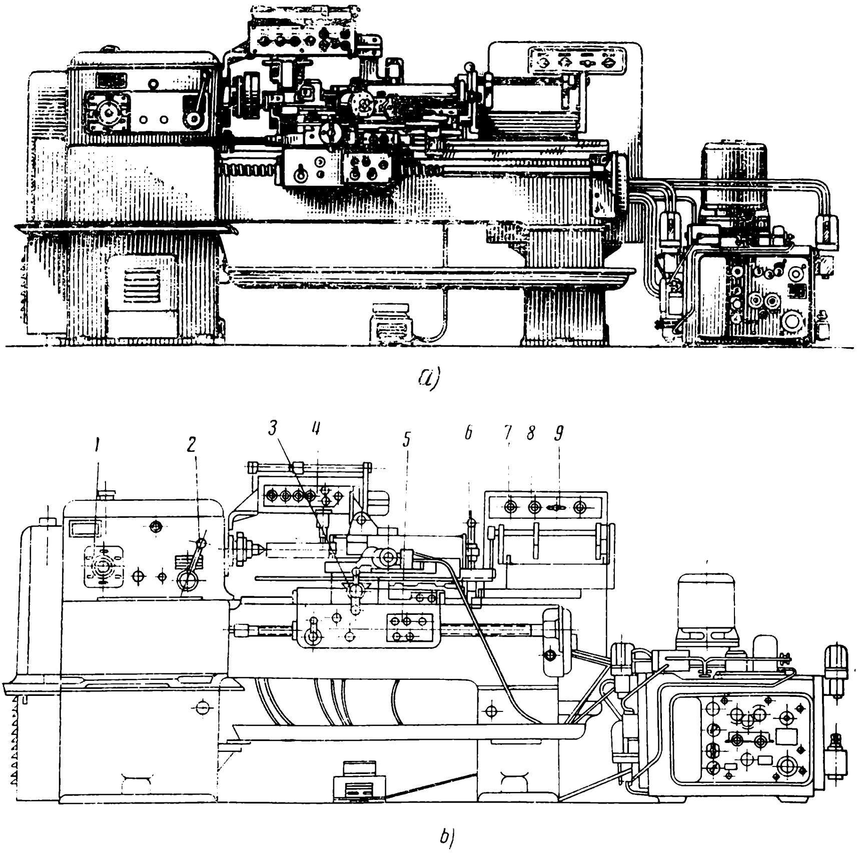


Fig. 74. General view (*a*) and control diagram (*b*) of the automatic programme-controlled production lathe, model 1C62.

1 and *2*—levers for changing spindle speeds, *3*—ball-crank handle for cross feed of slide, *4*—control panel of magazine feed device and for starting and stopping automatic cycle, *5*—control panel for work signals: "rapid traverse", "template", "hydraulic slide", *6*—tail-stock binding lever, *7*—selector switch for operation in one or two cuts, *8*—operating cycle switch: "Automatic", "Setting Up", *9*—main line switch.

The lathe is set up with a punched card.

The lathe bed is box-shaped and reinforced by transverse ribbing. The front way locates the saddle in its travel on the bed; the rear way locates the tailstock. Both are V-type ways.

Fig. 75 illustrates the kinematic diagram of the model 1C62 lathe.

The speed gearbox provides for spindle speeds in a range from 200 to 2,000 rpm. The speed gearbox is powered from an individual electric motor, located in the left-hand leg of the bed, through a V-belt drive.

Sliding gears are shifted by levers.

Longitudinal feeds are driven by a hydraulic motor, model MГ-154 (speed 1,000 rpm, developed torque 5 kg-m, oil consumption 50 l per min at 1,000 rpm, pressure 50 kg per sq cm) which transmits rotation through a reduction gear with $i=1:3.3$ to a lead screw (diam 40 mm, pitch 12 mm). The hydraulic motor is mounted at the right end of the bed.

The master switch is designed to send work signals which operate the automatic cycle. Electric contacts are made by tiny wire brushes through the holes of the punched card.

The punched card is of close cardboard, 0.25 mm thick, with a one-millimetre inscribed grid. This card is secured on the drum of the master switch in alignment with the "cycle start" index line.

The master switch is mounted in front of the bed, at the place where the quick-change gearbox is usually located. The master switch drum is driven from the lead screw.

The punched card (Fig. 76) has eight longitudinal lines or rows along which 4 mm holes are punched at the required places. Instantaneous electric contacts are made through these holes for transmitting the corresponding work signals. The first line is for the first feed, the second for the second feed, the third for rapid return travel, the fourth for the first feed of the second cut, the sixth for rapid return travel, the seventh for rapid approach, and the eighth for stop of left-hand travel.

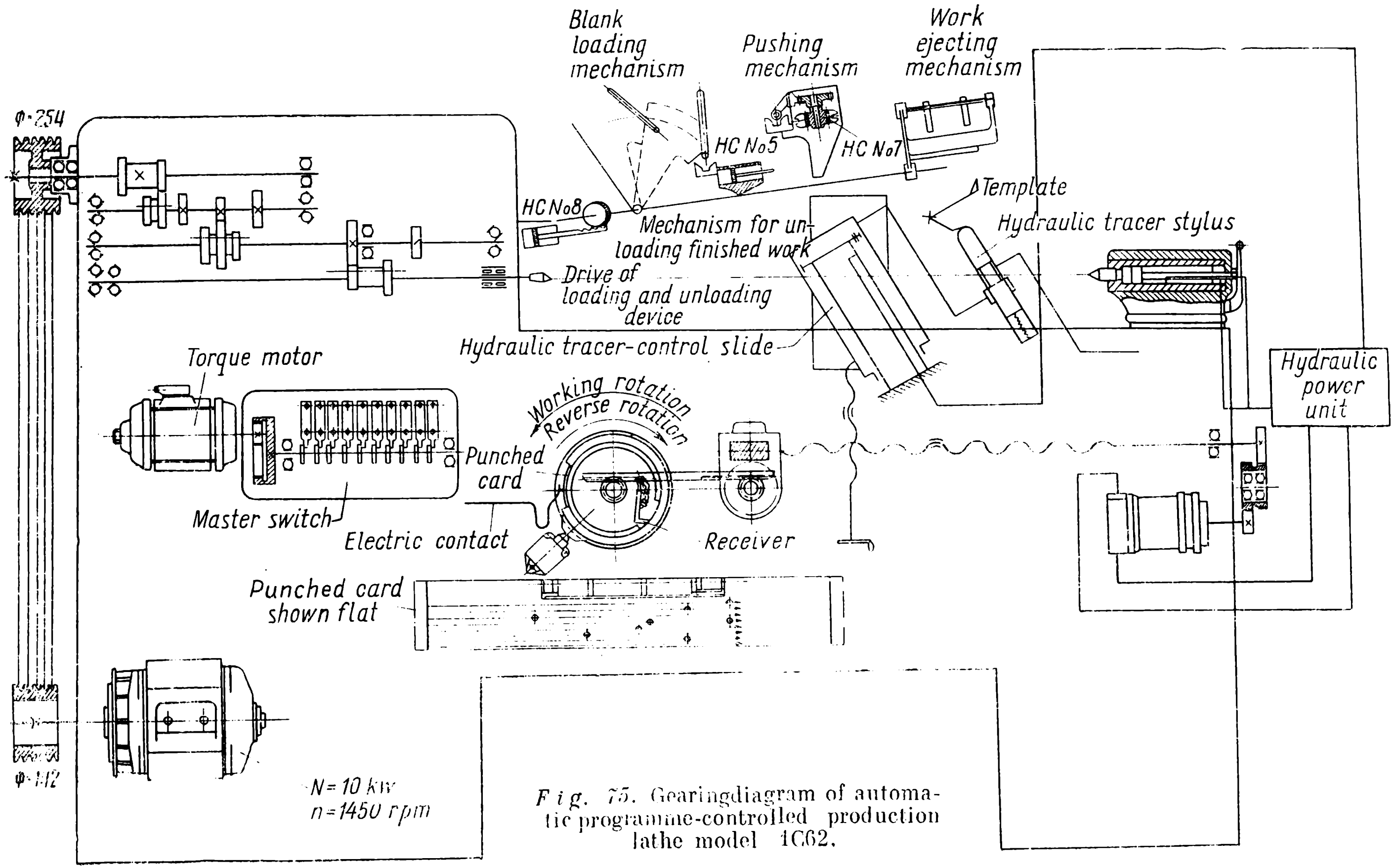
The work signal "stop, R. H. travel" (extreme position) is transmitted by a special limit switch tripped by a cam on the drum.

Hydraulic tracer-control slide. The lathe is equipped with a hydraulic tracer-control slide in which both the cutting tool and template are arranged in front of the line of centres. A rear facing slide may be installed in special cases.

The cutting tool is clamped, face downward for better chip disposal, in a rapid-change toolholder.

The workpiece contour is turned by a two-cut hydraulic tracer-control slide which operates with two templates. The lower is the roughing and the upper, the finishing-cut template.

The tailstock is hydraulically operated (see Fig. 74). Rapid and slow advance, rapid retraction, as well as clamping and unclamping the tailstock spindle are accomplished by hydraulic means.



F i g. 75. Gearingdiagram of automatic programme-controlled production lathe model 1C62.

In a semi-automatic cycle these above-mentioned operations are controlled by a pedal. Pedal and spindle operations are interlocked (the tailstock spindle cannot be retracted while the work spindle is in operation).

The *apron* has half-nuts with backlash adjustment and a hand-operated oil pump for lubricating the saddle ways, gibs, and half-nuts. A control panel on the front face of the apron provides for the following work signals: rapid traverse to the left, rapid traverse to the right, roughing template, finishing template, hydraulic tracer-control slide—on and off.

The *loading and unloading device* (see Fig. 75) consists of: 1) blank magazine, 2) drive, 3) mechanism for mounting the blank between the centres, 4) mechanism for unloading the finished workpiece, 5) mechanism for pushing the finished workpiece to the transfer trough, and 6) mechanism for ejecting the finished workpiece to the transfer trough.

The blank magazine is an inclined chute located between the headstock and the pusher-mechanism upright.

The magazine is, to some extent, universal in design and will accommodate work 25 to 60 mm in diameter and 140 to 370 mm in length. Simple adjustments will set up the magazine for a new workpiece.

The control panel and the work light are mounted in the magazine bracket.

The blank handling mechanism is actuated by a hydraulic cylinder through a spline shaft mounted at the rear of the bed.

The blank loading mechanism is mounted on the spline shaft and consists of a segment in the centre of which a lever and spring are mounted; two adjustable strips are mounted at the sides for gripping the blank. The segment oscillates through a definite angle, selected to suit the blank diameter. The angle of oscillation of the segment is varied by changing the stroke of the piston which feeds the blank from the magazine to the line of centres.

A stop, secured to the unloading mechanism, and the stop screw of the blank grip lever spring enable the blank to readily enter the loading mechanism segment.

The mechanism for unloading the finished workpiece is operated by a hydraulic cylinder which traverses a plunger with a V-block in the cross direction.

At the end of the machining operation, the V-block is advanced to a position under the line of centres; the finished workpiece drops into the V-block and the mechanism is then retracted to its initial position.

The mechanism for handling the finished workpiece is actuated by a hydraulic cylinder which traverses a rack, on which a stop screw is mounted, in a longitudinal direction.

After the unloading mechanism has returned to its initial position, the stop screw runs against the end of the workpiece and pushes it

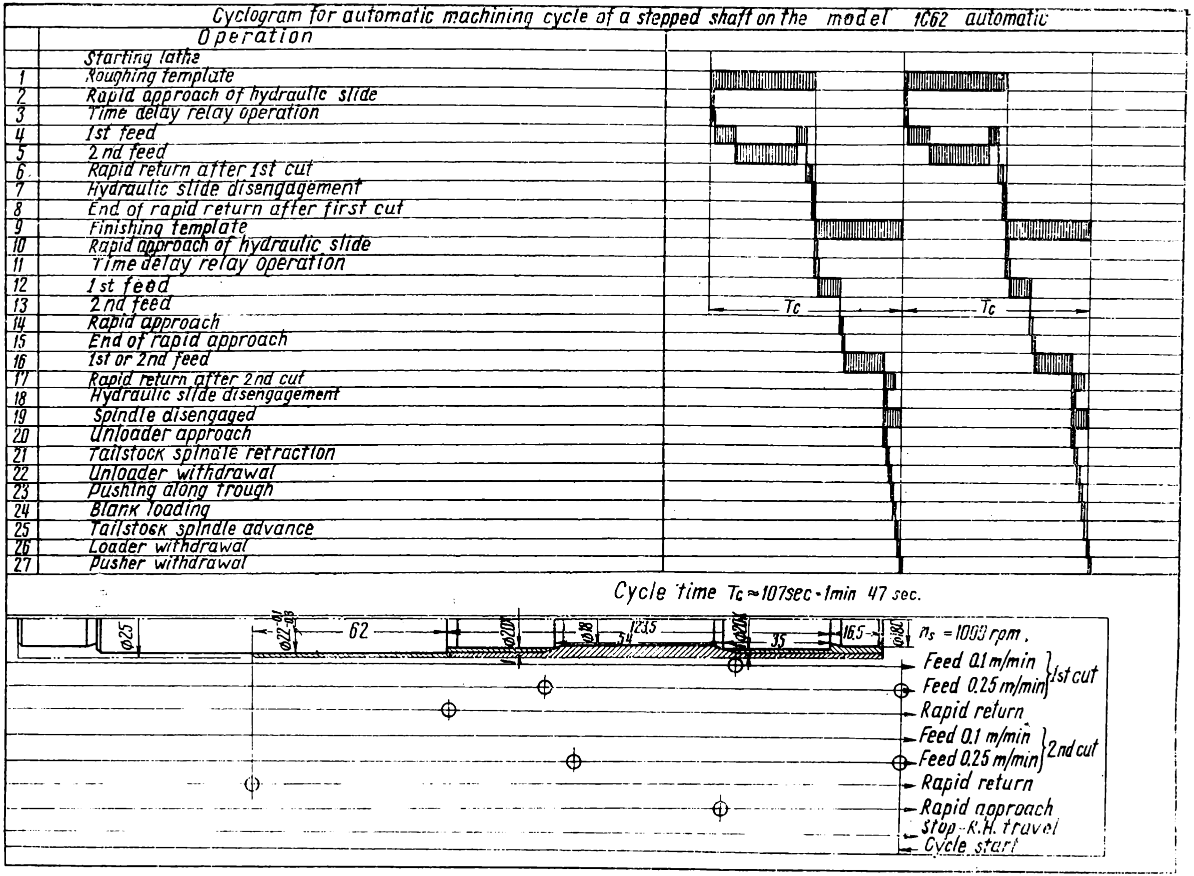


Fig. 76. Cyclogram for turning a stepped shaft on automatic lathe, model 1C62 (stepped shaft is shown on the punched card).

through a distance somewhat exceeding the length of the workpiece (the stroke of the rack is adjusted with a screw).

In the following cycle, the preceding workpiece is pushed farther by a new workpiece.

A finished workpiece is ejected to the transfer trough at the same time that a new blank is loaded. This mechanism is designed with adjustment, to accommodate various work lengths and a range of diameters, by means of levers that are adjusted along the length of the spline shaft and on its diameter.

The automatic is equipped with chucks having self-clamping jaws for holding a definite range of work diameters. Their operation is based on the following: when the spindle stops, the jaws are held open by springs and the blank can easily be mounted between the centres. When the spindle starts rotating and reaches a high speed, centrifugal force, acting on weighted levers, will bring the jaws tightly up against the blank surface. Then, when the tool begins to cut, the cutting force will instantly jam the blank in the jaws.

An automatic gauging attachment may be mounted on this lathe. This attachment switches off the lathe drive when the gauged dimension on the workpiece is not within the permissible limits.

A cyclogram for turning a stepped shaft and a punched card for controlling all movements of this cycle are shown in Fig. 76.

The use of programme-controlled lathes enables the handling time to be substantially reduced and sharply increases the rate of production not only for mass but also for lot production.

Part Two

EFFICIENT OPERATION OF AUTOMATIC AND SEMI-AUTOMATIC LATHES

CHAPTER I

PRINCIPAL COMPONENTS OF THE MANUFACTURING PROCESS

§ 41. THE MANUFACTURING PROCESS

The manufacturing process, as we have called the sequence of machining operations, is the sum-total of all actions required to change the shape, dimensions, and physical properties of a blank to comply with the part drawing and the specifications.

The manufacturing process comprises a series of separate operations, each performed at a single workplace.

Operations are subdivided into operation elements, also called settings or stations. These include the part of an operation that is performed at one station or position of the machine tool and with a single setting of the work or cutting tool.

Each operation element may consist of several passes or cuts. These may be roughing, semi-finishing or finishing cuts.

The following types of machining may be performed on automatic and semi-automatic lathes:

a) turning external cylindrical, tapered, and form surfaces and facing;

b) drilling, core drilling, reaming, and boring cylindrical or tapered holes;

c) turning annular grooves, fillets, and corner radii, recessing and chamfering;

d) cutting external and internal thread;

e) rolling thread and knurling;

f) cutting off.

The detail drawing is the main and comprehensive document specifying all requirements with which the form and quality of the workpiece are to comply.

The detail drawing should indicate the part name, the material of which it is to be made and the type of blank specified, all dimensions and tolerances, required geometrical form accuracy (out-of-roundness, taper, etc.), surface finish, and heat treatment. Dimensional tolerances may be shown as numerical values or as fit symbols.

Other manufacturing specifications are also often indicated in part drawings.

A generally-accepted rule of engineering production is that no one except the designer is authorised to make any changes whatsoever in the drawings.

§ 42. MACHINING ACCURACY

In any manufacturing process, the actual dimensions and shape obtained on the workpiece will inevitably deviate from the nominal size indicated in the detail drawing. Even workpieces of a single batch or lot will differ from each other to some extent.

By part accuracy we mean the permissible deviations in nominal size and form with which a workpiece may still conform satisfactorily with the specifications and will function properly when assembled in a mechanism. The conceptions of tolerances, class of accuracy and part interchangeability are based on this principle of "Good enough being best" for the purpose in view. *The smaller the permissible deviation, i. e., the narrower the tolerance, the higher the machining accuracy must be and the more complex and expensive manufacturing methods will be required.*

The higher the class of accuracy, the lower the number symbol by which it is denoted (the 1st is the highest class) and the narrower the limits of dimensional variation permitted in manufacturing the workpiece.

Various tolerances may be selected to suit the function of the part in the assembled mechanism. Narrow tolerances are assigned to the more important surfaces and wide tolerances to non-mating surfaces.

Tolerances are indicated in the detail drawing as supplementary figures following the dimensions and arranged slightly above or below them. If the permissible deviation may only increase the main dimension, the tolerance is placed slightly above and has a plus (+) sign; if the deviation only reduces the dimension, it is placed below with a minus (—) sign, and, finally, if the tolerance is bilateral, i. e., if the main dimension can be both decreased and increased, the tolerance is shown on a line with the dimension and with a plus-minus (±) sign.

Parts which are to be mated together should be manufactured to tolerances which provide either for more or less freedom in their relative movement or for proper rigidity in fixed associations. The character of the association obtained between two mating parts is determined by the specified fit which also has definite tolerances. Fits are denoted by letter symbols with subindexes following the dimension they refer to. This designation indicates the grade of accuracy, name and character of the fit. Only fine fits (2nd grade of accuracy) are denoted by a letter symbol alone without the subindex. The dimension $\phi 20A$ *, for example, indicates that a hole, 20 mm in diameter, is to be machined to the 2nd grade of accuracy. The actual tolerance values, in accordance with the type of fit and its size, may be taken from handbook tables. The dimension $\phi 20A_1$ indicates that a hole 20 mm in diameter *should be finished to the first grade of accuracy in the hole system of fits.* The tabular tolerance for this fit will be +0.013 mm. The dimension with its tolerance may be set down as $20^{+0.013}$ mm. Another example, $\phi 20X$ indicates that a shaft with a nominal diameter of 20 mm should be manufactured to a *running fit in the second grade of accuracy and again in the hole basis system.* The tabular tolerance for this fit will be $^{-0.025}_{-0.085}$ and

Table 3

Approximate Data on Attainable Machining Accuracy on Automatics and Semi-Automatics

Types and bar capacities or chucking capacities, mm	Maximum out-of-roundness, mm	Maximum taper (difference in diameter), mm, per length, mm	Maximum size (diameter) variations in a single lot, mm
Swiss-type automatic screw machines:			
3 to 6.5	0.01	0.01 per 50	0.02
6.5 to 10	0.01	0.01 per 50	0.03
16 to 25	0.01	0.02 per 100	0.04
Automatic screw machines:			
10 to 16	0.015	0.02 per 50	0.04
25 to 40	0.015	0.03 per 100	0.05
Single-spindle semi-automatic lathes:			
80 to 100	0.015	0.03 per 100	0.08 *
120 to 200	0.020	0.03 per 150	0.10 *
250 to 300	0.030	0.03 per 200	0.15 *
400 to 500	0.040	0.03 per 250	0.20 *
Multiple-spindle automatic bar machines:			
25 to 40	0.015	0.03 per 100	0.08
65 to 100	0.020	0.03 per 150	0.10
Multiple-spindle semi-automatic chucking machines:			
80 to 100	0.015	0.03 per 100	0.10
120 to 200	0.020	0.03 per 150	0.12
250 to 300	0.030	0.03 per 200	0.20
400 to 500	0.040	0.03 per 250	0.25

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* Higher accuracy is attainable for hydraulic tracer-controlled lathes.

the dimension with the tolerance will be $20^{-0.025}_{-0.085}$. This means that the shaft limits will be 19.915 and 19.975 mm.

If each part of a certain model of a machine is to fit any mating part of the same model, regardless of the lot to which it belongs and when it was made, it will be necessary for the same parts to conform to the same tolerances. In such cases, the parts are said to be *interchangeable*.

In manufacturing machine parts, in addition to dimensional accuracy, it will be necessary for the work to comply with specifications concerning the accuracy of geometrical form (parallelism or squareness of surfaces to each other, alignment of cylindrical surfaces, etc.) and the quality of surface finish (maximum permissible height of surface irregularities).

Third and fourth grades of accuracy are economically attainable, as a rule, on automatics and semi-automatics. The second grade of accuracy may be maintained if special attachments and cutting tools are employed.

Approximate data on attainable machining accuracy on automatics and semi-automatics are given in Table 3.

The surface finish of work produced in these machines depends on the tools used to machine the surfaces. *The finer the finish, i. e., the lower the surface irregularities, the higher the class of surface finish.* Usually a surface finish of $\nabla 3$ to $\nabla 6$ is obtained on these lathes, but in particular cases, a surface finish of $\nabla 7$ or even $\nabla 8$ may be achieved.

§ 43. STOCK AND BLANK SELECTION

Selection of the type of blank or stock from which a part is to be made is a decisive factor in planning the manufacturing process and in economic production.

Automatic lathes use wire in coils, bar stock, pipe and separate blanks. Coiled wire stock is rarely over 6 mm in diameter. Bar stock is available in a great variety of shapes and sizes, but it is considered poor practice to use stock over 50 mm in diameter since the waste metal in the form of chips will be excessive.

Only separate blanks are used on semi-automatic lathes. They may be in the form of castings and hammer or die forgings.

The nearer the blank approaches the finished workpiece in form and size, the less material will be required for manufacture and the less metal need be removed in machining. This will reduce the number of operations, operation elements and passes required in production. The production time will be correspondingly reduced and the number of workpieces machined on each lathe in a unit of time will be increased. The final result will be a reduction in the manufacturing cost of the article being produced.

The most accurate blanks are obtained by die-forging or die-casting since these processes ensure minimum dimensional errors in the various elements of the blank. These processes are inherent to mass and large-lot production and are not economically feasible, as a rule, for small lots.

Blanks in ordinary lot production are usually grey iron or non-ferrous castings, steel forgings and billets cut off of bar stock or pipe. Comparatively large amounts of metal are removed in machining such blanks since they have large allowances for this purpose.

§ 44. MACHINING ALLOWANCES

The allowance is the difference between the size of the stock or blank and that of the finished workpiece specified by the detail drawing.

Allowances are classified as the *total allowance*, the layer of metal removed in all operations and their elements, and the *operational allowance*, removed in each particular operation.

Blanks should be selected to obtain minimum possible allowances.

The principal dimensions given in blank and part drawings of work produced in lathes are diameters and lengths. The allowance on each side will equal one half of the difference between the diameters of the blank and the finished work.

For example, if diameter D of the blank equals 50 mm and the corresponding diameter d of the finished part is 40 mm, the allowance on each side will be:

$$a = \frac{D-d}{2} = \frac{50-40}{2} = 5 \text{ mm}.$$

This means that the cutting tool must be fed into the blank 5 mm to obtain the 40 mm diameter, i. e., the blank must be turned with a depth of cut $t=5$ mm.

The larger the size (diameter and length) of the workpiece, the larger the allowances required in machining.

Allowances required on each side for turning work of bar stock will be 1 mm for work diameters up to 12 mm and 2 mm for larger work. An allowance from 3 to 5 mm on each side may be used for large blanks over 100 mm in diameter.

The length allowance for cutting off bar stock is usually from 2 to 4 mm while the allowance for facing is from 1.5 to 2 mm.

A length allowance of 3 to 5 mm is required for blanks cut off by a power hacksaw or metal-cutting circular saw. Bar stock is usually subjected to straightening on special straightening and sizing machines before turning operations are performed.

§ 45. WORKPIECE LOCATION

A blank (or bar stock) must be properly located to ensure a correct, accurate, and reliable position in relation to the axes of spindle or cutting tool rotation. This position of the work must not change during the machining process.

Surfaces which locate the workpiece for machining are called *datum surfaces.*

Handling convenience and cycle time depend to a large extent on the method adopted for locating and clamping the blank. Wire, bar stock and pipe are located on their outside diameters (which should be, therefore, as accurate as possible), while the length is located by a stock stop.

The following types and combinations of datum surfaces are applicable for separate blanks:

a) *outside cylindrical surface and one end face*, b) *external or internal cylindrical surface and face on one end with a centre-hole on the other end*, c) *hole and one end face*, and d) *two centre-holes.*

Locating surfaces should be selected so as to ensure minimum distortion of the blank from the clamping force.

§ 46. MACHINE TOOL SELECTION

The most suitable machine tool should always be selected among those available for each machining operation. Any part may be machined by many different methods and on various types of machines. Therefore, it is not sufficient to establish the possibility of processing a given part on a given machine tool. *The processing engineer must make sure that the given work may be most efficiently produced in the required quantities on the given machine tool, i. e., with the least expenditure of materials and labour and, therefore,at the least cost.*

Multiple-spindle automatics and semi-automatics find their most efficient application for mass production. Single-spindle machines are more expedient for large-lot production.

New designs of automatics and semi-automatics, developed in recent years by Soviet engineers, may be efficiently employed for small-lot production as well.

Machine tool selection should always be based on the feasibility of processing a given job with the specified accuracy and at the desired rate of production. The accuracy of work turned on single-spindle machines is usually higher than on multiple-spindle models.

Expedient application of a given automatic or semi-automatic lathe to the production of a definite part in the prescribed quantities is determined by the rate of production and the cost (methods for the calculation of these factors are given in Part Five).

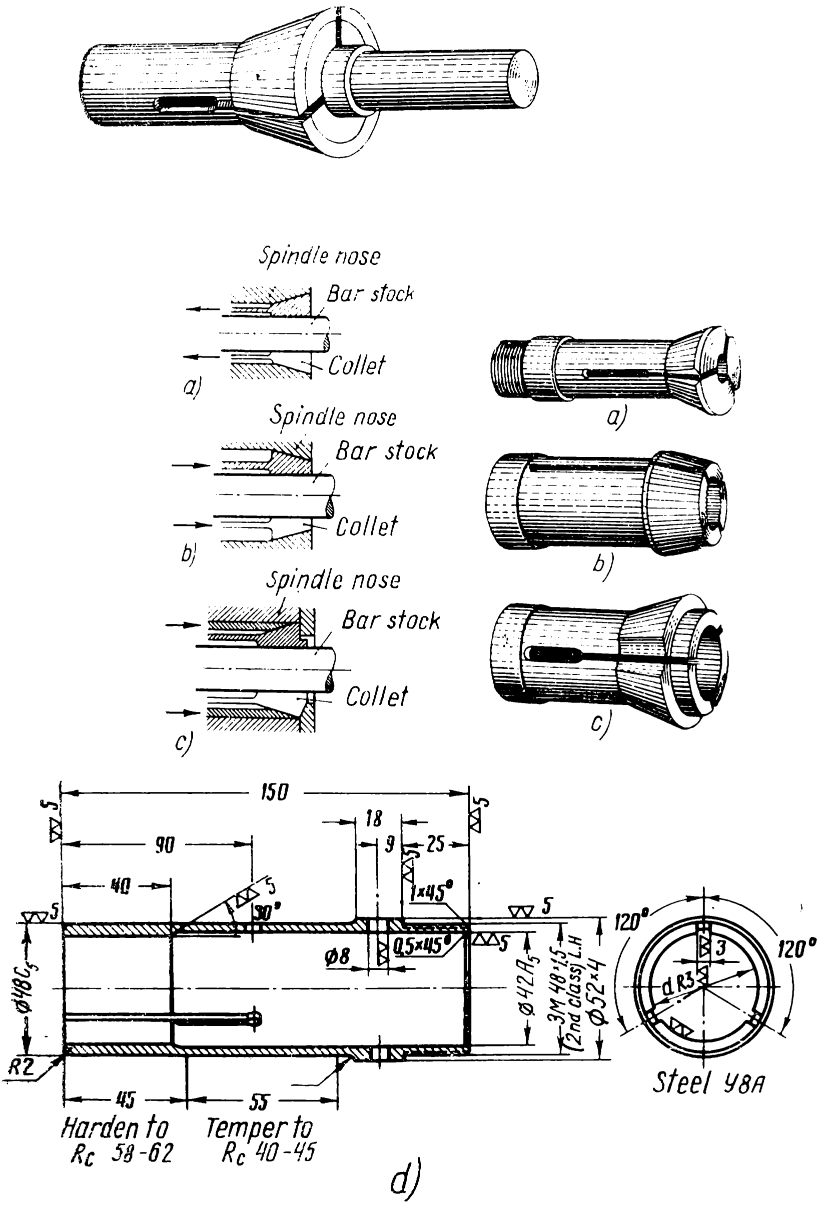


Fig. 77. Spring collets and feeding finger.

a, *b*, and *c* — spring collets and clamping principles, *d* — feeding finger (stock pusher)

§ 47. SELECTION OF THE STOCK FEEDING AND CHUCKING DEVICES

A chucking device must clamp the stock or blank reliably and rotate it with an accuracy that guarantees finished work of the specified form and size.

In automatic machine tools, the chucking device clamps and releases the work automatically (without the participation of the operator) and in minimum time.

A spring collet chuck, arranged in the work spindle, is commonly used in automatic bar lathes. Three types of spring collets, widely employed in automatics, are illustrated in Fig. 77 *a*, *b*, and *c*.

In the construction of Fig. 77 *a*, the spring collet is pulled by the collet tube to the left into the taper bore of the spindle nose. This action puts pressure on the tapered sections of the collet, forcing them inward and tightly clamping the bar stock.

The collet tube in Fig. 77 *b* pushes the spring collet to the right into the tapered seat in the spindle nose. This clamps the bar stock in the same manner as before.

The spring collet has no axial movement in the design of Fig. 77 *c*. This chuck is closed when the collet tube pushes a sleeve with an internal taper onto the taper of the collet, forcing it inward to clamp the stock.

Spring collet chucks locate the work with high accuracy. Bars up to 12 mm in diameter, clamped in a collet chuck, will run true on a length of 30 or 35 mm to within 0.02 or 0.03 mm. Bar stock, 40 mm in diameter, will run true within 0.05 mm on a length of 100 mm.

In the chucking arrangement shown in Fig. 28, the bar is clamped by the spring collet *16*, on which the sleeve *15* is pushed by the collet tube *7*. The internal taper of the sleeve closes the collet.

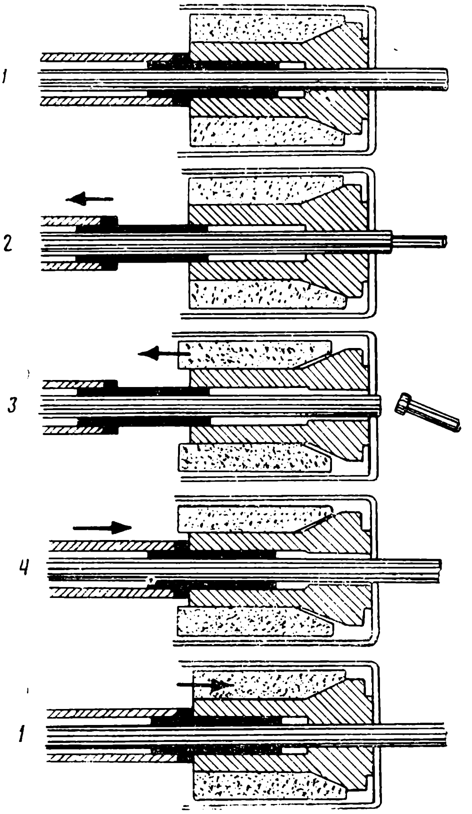


Fig. 78. Operation of the bar stock. feeding and chucking mechanisms

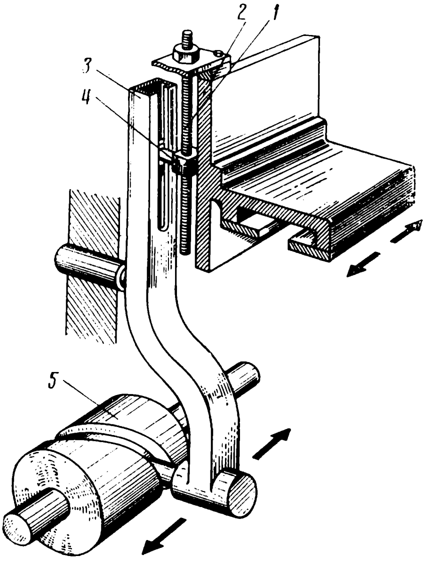


Fig. 79. Mechanism for adjusting length of bar stock feed in machines with collet type chucking facilities.

The collet tube is actuated by the chucking levers *5* which rotate in reference to the sliding ring when the sleeve *4* is shifted. The collet is released rapidly due to spring *13*, located between the collet and sleeve *15*. This spring retracts the collet tube when the levers *5* are released by sleeve *4*. The chucking mechanism is operated from a cylinder cam through a system of levers. The design of collet *16* is shown in more detail in Fig. 77 *c*.

In automatic bar machines, the feeding tube is arranged inside the collet tube and carries a spring feeding finger (also called stock pusher) (Fig. 77 *d*) screwed on its front end. The feeding finger is a slitted spring bushing in which the jaws were compressed or closed before heat treatment. The jaws maintain a constant grip on the stock sufficient to feed the bar forward the moment it is released by the collet chuck.

The spring action of the jaws should not be excessive, however, so that the feeding finger may be drawn back over the stock to the initial position when the bar is clamped.

Bar stock feed and chucking proceed in the following order (Fig. 78): *1* — bar stock is clamped, *2* — feeding finger is retracted, *3* — work is cut off and collet opens, *4* — feeding tube and finger feed the bar out (to the right) up to the stock stop. After this, the stock is clamped by the movement of the collet tube *7* (see Fig. 28). When the collet *16* grips the bar, the feeding tube *6* is returned to its initial left position and the feeding finger *14* slides along the clamped bar.

The feeding tube is operated by permanent cylinder cams *5* through the lever system *3* (Fig. 79) and slide *2*. The amount of stock feed is adjusted with screw *1* by setting the sliding block *4* into the required position in the slot of rocker arm *3*.

A great variety of chucking and clamping devices are employed for semi-automatic lathes. They clamp the work either on internal or external surfaces according to the locating method adopted.

Mechanical and pneumatic work holding devices are illustrated in Fig. 80 *a* and *b*. Their principle of operation is the same; it is based on shifting a rod which simultaneously swivels levers linked to the clamping jaws. They differ in that the rod is operated mechanically in one chuck and by air pressure in the other. It is evident that hydraulic pressure or electro-mechanical power can also be employed for chuck operation.

A chuck for holding hollow workpieces, located on the bore, is shown in Fig. 80 *c*.

A tailstock is needed to turn work between centres on a semi-automatic lathe. In the hydraulic-action tailstock, shown in Fig. 80 *d*, the tailstock spindle is advanced and retracted by hydraulic power. Its use will enable the time for mounting, clamping, and releasing the work to be substantially reduced. These handling operations may also be made fully automatic.

Separate blanks are loaded by hand into semi-automatic lathes. In automatics, they are fed to the working position by magazine loading devices which contain a number of blanks.

§ 48. MAGAZINE LOADING DEVICES

Automatic loading or feed devices for separate blanks are employed on many types of single- and multiple-spindle automatics. Their design depends mainly on the form of the blank. Blanks should, of course, be sufficiently accurate in size and form. Automatic magazine loaders are often applied for second-operation work, as well as for turning precise forgings or castings.

Magazine loading enables full automaticity to be achieved. This allows operators to attend several machines at the same time and to sharply increase the productivity of their labour.

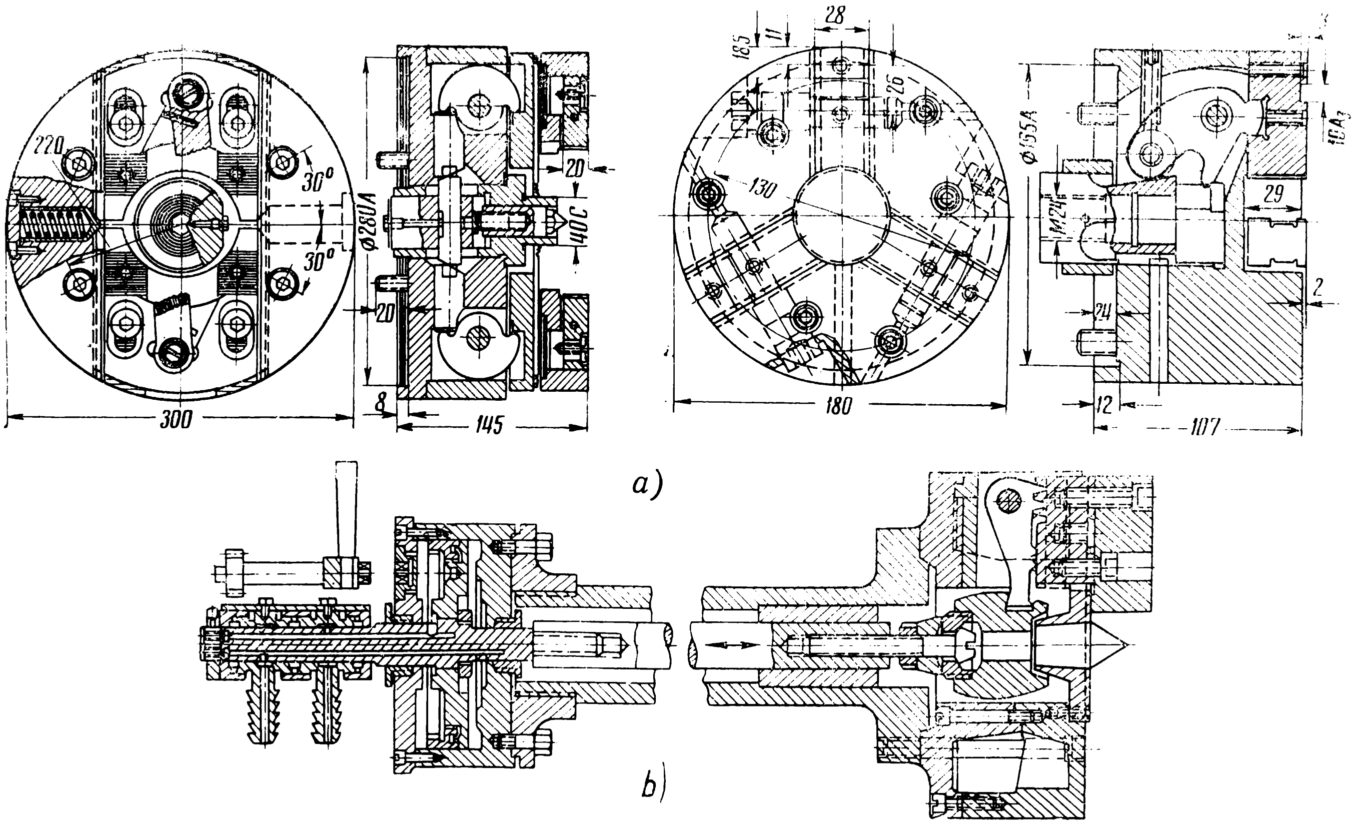
Automatic loading and unloading devices provide the basis for connecting separate machine tools into automated sequences or automatic transfer machines.

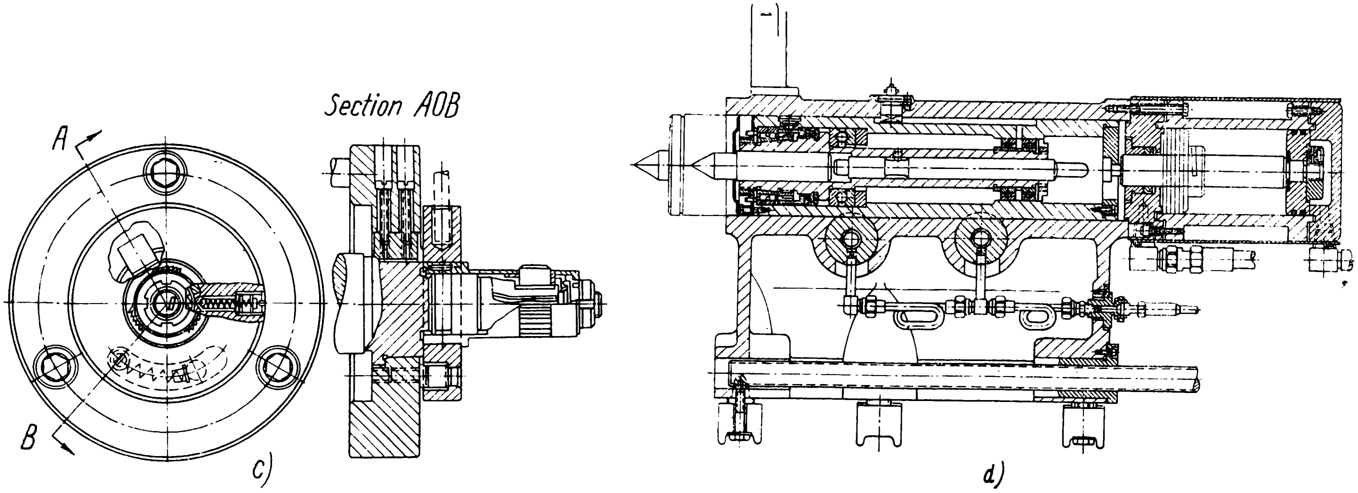
Magazine feed devices, mounted at the spindle nose (Fig. 81 *a* and *b*), feed the blank into the collet chuck. The device may be secured to one of the cross toolslides which periodically advances to the spindle, carrying the lower of a stack of blanks into the loading position. A spring-loaded pusher, mounted on the turret or end toolslide, pushes the blank into the collet chuck of the spindle. The spring compensates for differences in blank length.

The bar stock feed mechanism of the automatic is used in this case as a work stop and then as an ejector which pushes the finished workpiece out of the chuck.

The application of magazine loaders to semi-automatic lathes (Fig. 81 *c*) converts them into automatics.

Magazine feeds, employed on multiple-spindle chucking machines enable them to be used for fully automatic operation. The magazine may be arranged at the spindle nose at the loading position. One of the side toolslides, removes the lower blank of the stack


30°
30°
Ø280A
Ø155A
M24
16A3
a)
b)



F i g. 80. Work holding devices for separate blanks.

a and *b* — chucks for clamping on the outside diameter (mechanical and pneumatic types) *c* — chuck for clamping on the bore, *d*—hydraulic-action tailstock.

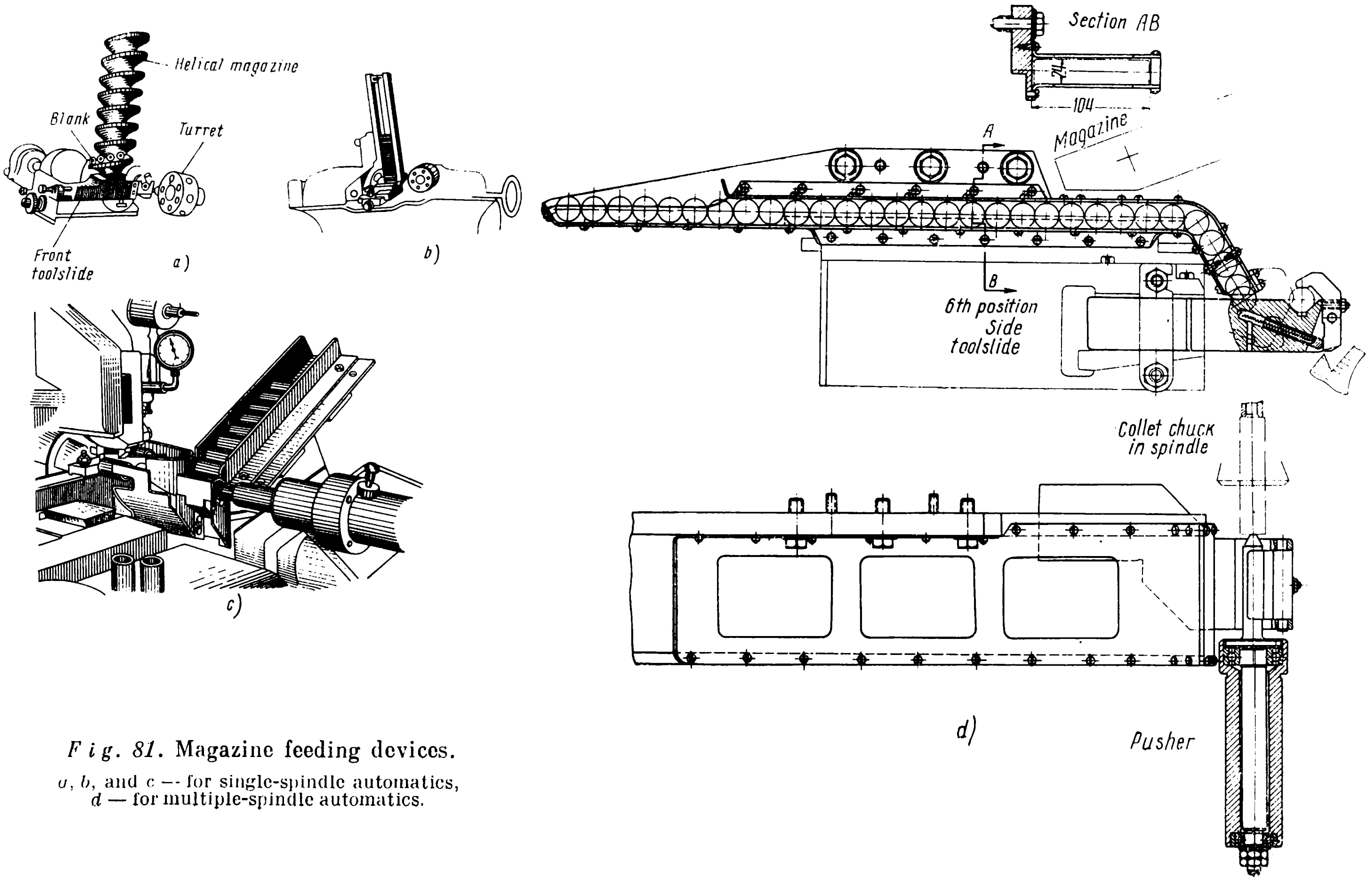


Fig. 81. Magazine feeding devices.

a, *b*, and *c* — for single-spindle automatics, *d* — for multiple-spindle automatics.

after each carrier indexing, and feeds it into alignment with the work spindle. Here it is pushed into the chuck by a device mounted on the end toolslide (Fig. 81 *d*).

In some cases, blanks are fed into machine tools by magazines which operate in conjunction with automatic work handling devices (mechanical hands). The latter may operate independently to transfer work directly from one machine to the next.

An automatic handling device is shown in Fig. 82 *a*. It is designed for loading single-spindle centre-type lathes with blanks held in a magazine mounted at the rear. A hydraulic cylinder feeds the work into alignment with the lathe centres. After the blank is clamped between the centres, the piston reverses. First the cheek of the blank holder swings down and then the transfer mechanism is free to return to its initial position in which the next blank drops into the holder.

An automatic handling device for single-spindle automatic lathes is shown schematically in Fig. 82 *a*. Fig. 82 *b* shows a device for transferring bearing ring blanks from one multiple-spindle chucking machine to another in a bearing plant. The application of such devices enabled turning operations on both sides of the rings, as well as on other parts, to be completely automated.

§ 49. CUTTING TOOLS AND TOOLHOLDERS

Cutting tools and toolholders are selected after the processing method and machine tool have been finally established.

A large variety of standard and special cutting tools and toolholders are used on automatic and semi-automatic lathes.

Special tools and holders may be resorted to only in cases when the standard types are not applicable or when their use will lower the rate of production.

The principal types of cutting tools and toolholders and their applications are illustrated in Figs. 83 and 84.

In addition to these tools, drills, core drills, reamers, taps and solid dies, self-opening dies and collapsible taps, and knurling devices are extensively employed.

Cutting tools may be manufactured of carbon tool steel or high-speed steel or they may be tipped with cemented carbides or ceramic tool materials.

High-speed steel and cemented carbides are chiefly used. In the last years, high-speed steel has yielded to the more efficient cemented or sintered carbides which permit much higher cutting speeds and sharply increase the rate of production.

One obstacle to the extensive use of cemented carbides for automatics is the difficulty of manufacturing form tools of this material.

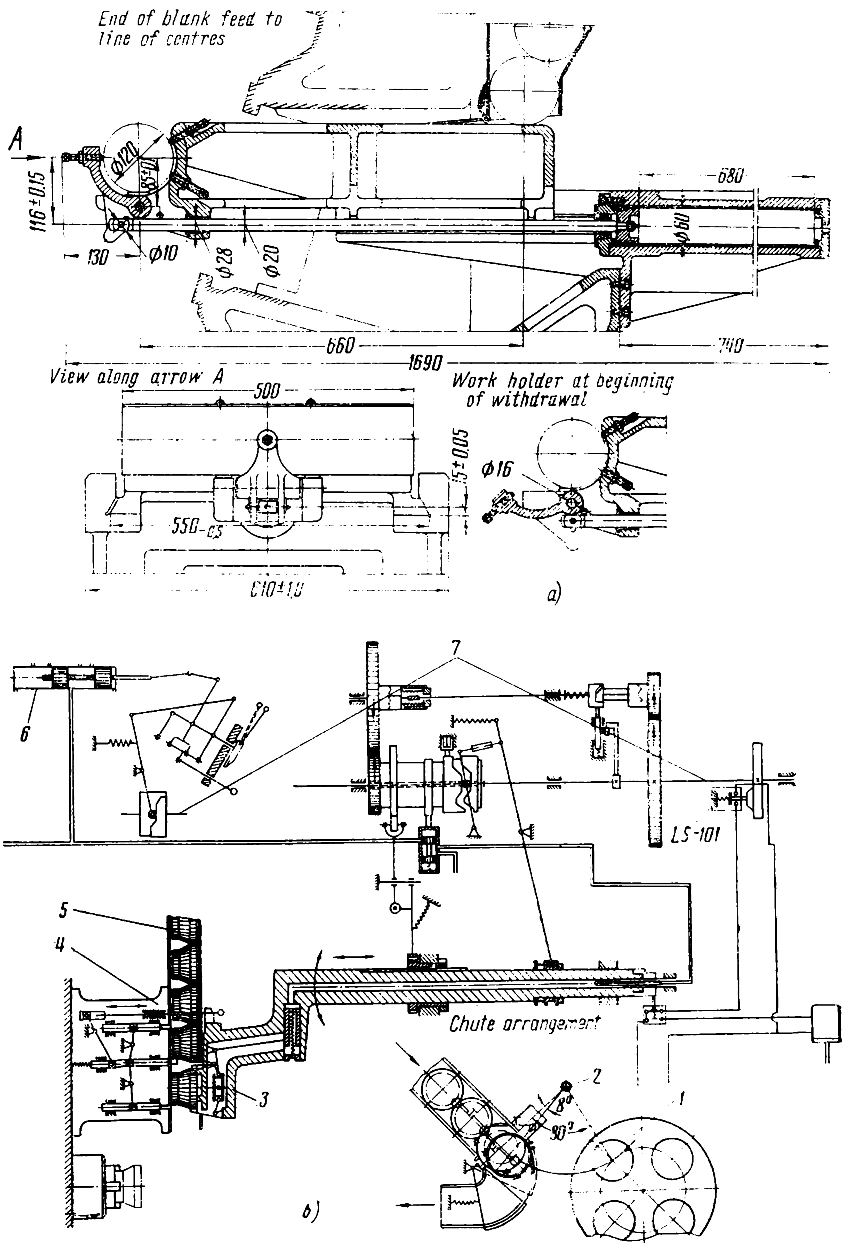


Fig. 82. **Automatic work handling devices.**

a—for single-spindle automatics, *b*—for multiple-spindle chucking machines: *1*—spindle in loading position, *2*—pivot of gripping device, *3*—feed-in chute, *4*—gripping device, *5*—magazine, *6*—blank, *7*—camshaft.

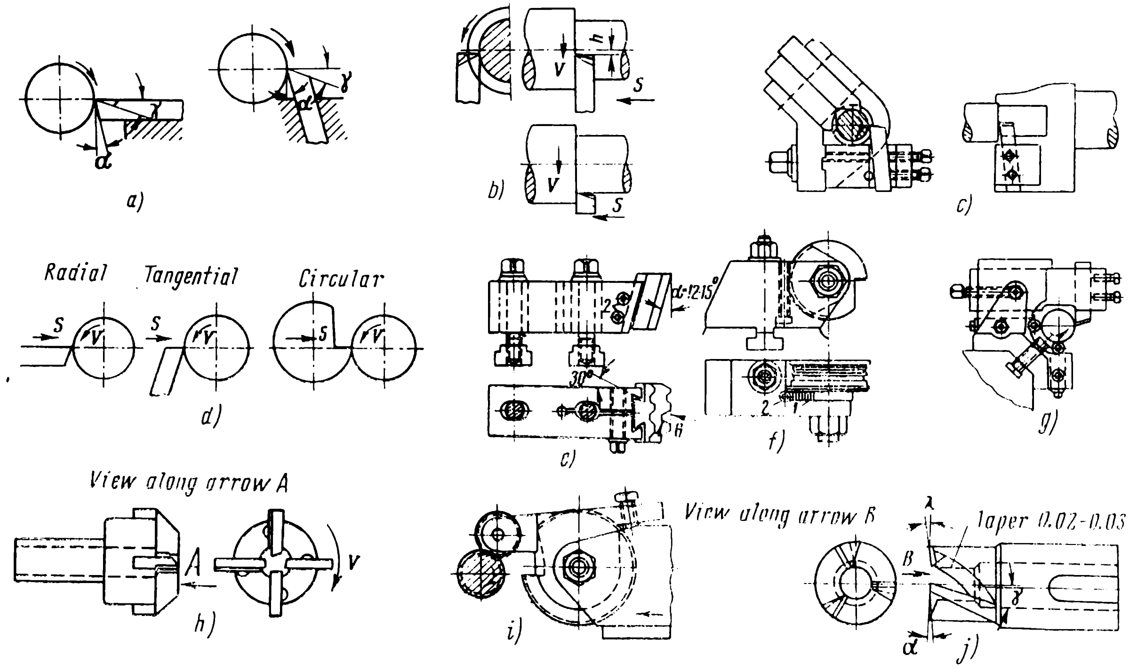


Fig. 83. Cutting tools and toolholders for automatic screw machines.

a — straight-turning: radial and tangential types, *b* — tangential tool, *c* and *g* — box tool (holder for tangential blades), *d* — cross cutting tools, *e* — holder for wide and forming tools, *f* — circular toolholder, *h* — inserted-blade hollow mill, *i* — holder for knurling and cut-off tools; *j* — plain hollow mill.

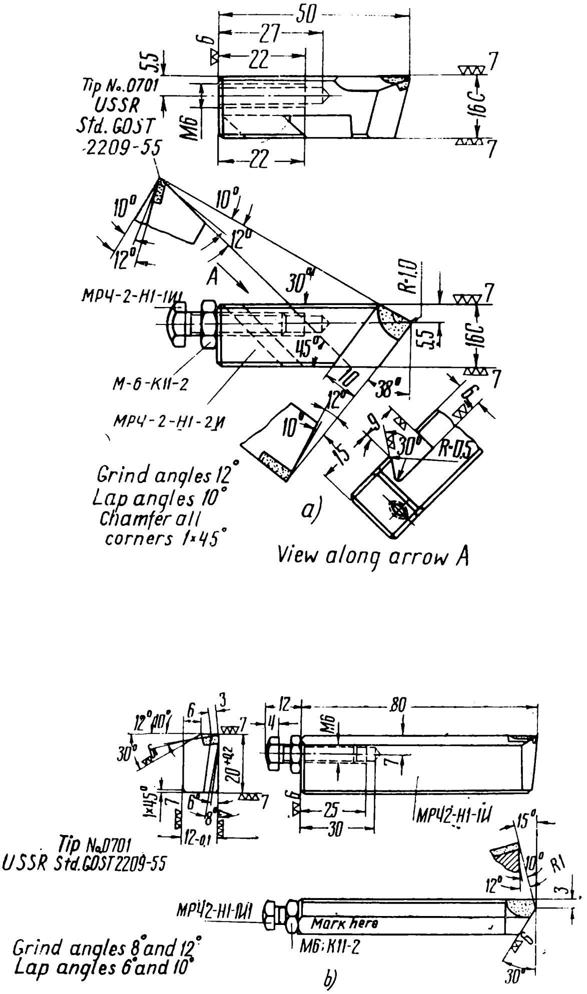
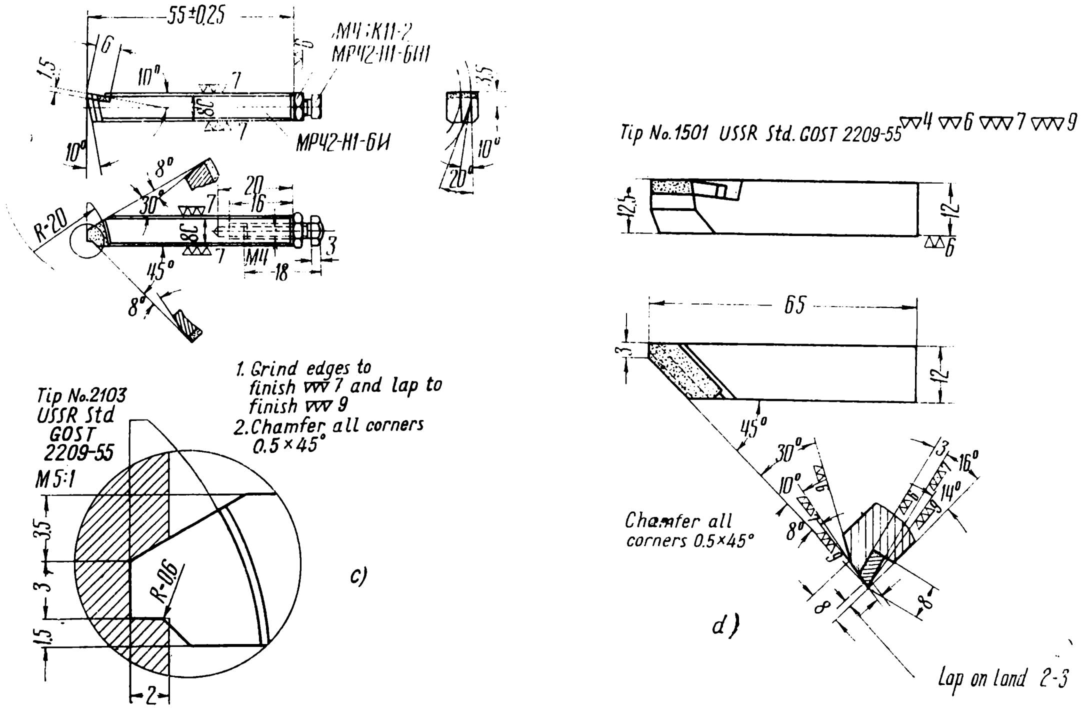


Fig. 84. Single-point tools with cemented-carbide tips for multiple-spindle automatics.

a — straight turning, *b* — facing.

(Continued)



Tip No.2103 USSR Std GOST 2209-55 M 5:1

1. Grind edges to finish ▽▽▽7 and lap to finish ▽▽▽9
2. Chamfer all corners 0.5×45°

Tip No.1501 USSR Std. GOST 2209-55 ▽▽4 ▽▽6 ▽▽▽7 ▽▽▽9

Chamfer all corners 0.5×45°

Lap on land 2-3

Fig. 84.

c — grooving, d — chamfering.

(*Continued*)

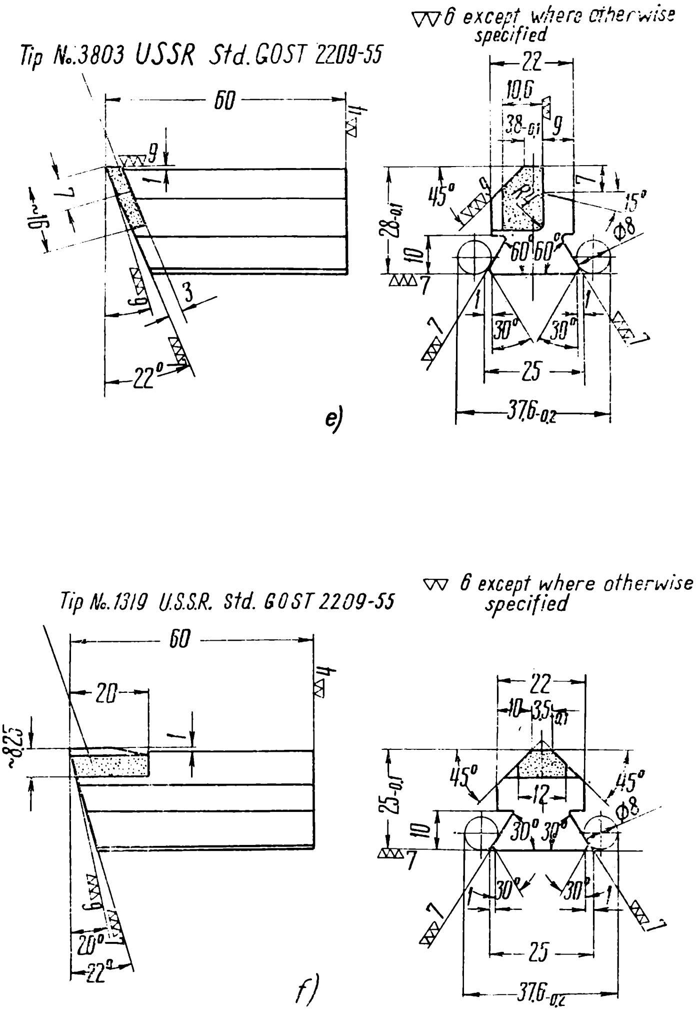


Fig. 84.

e and f — forming.

§ 50. MEASURING TOOLS

Measuring tools are selected to suit the manufacturing accuracy specified by the fits and tolerances of the detail drawing. Since automatic and semi-automatic lathes are employed chiefly for mass and large-lot production, plug limit gauges are used for hole inspection and snap limit gauges for external dimensions (Fig. 85). Measuring instruments (Fig. 86) are also used. In the latest designs of machine tools, the measuring devices are linked to the control system so that if the size of the workpiece approaches the permissible limits of the specified tolerance, the automatic gauge will hold up the work, stop the machine and signal the operator. This is called *passive control*. Still newer automatic gauging facilities reset the cutting tools to compensate for their wear. This is known as *active control*.

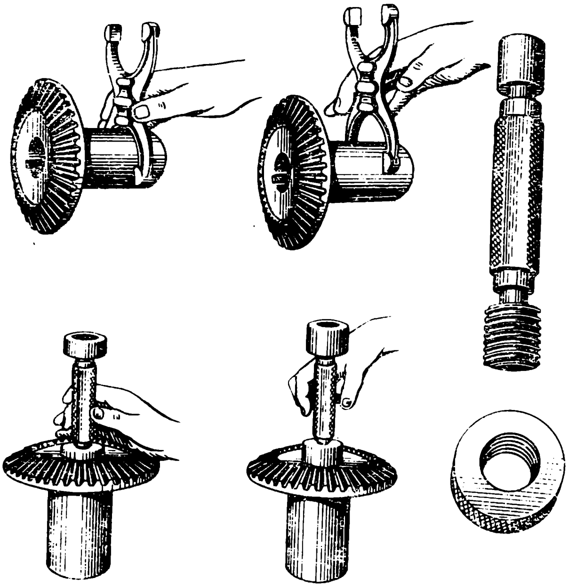


Fig. 85. Limit gauges for external and internal surfaces.

Work inspection devices, which are units of machine tools and which participate in the machining cycle, may be classified as 1) gauges for post-process inspection, 2) gauges for in-process inspection, and 3) devices for sorting the finished work into dimensional groups. Instruments, built into the machine tool, may have either passive or active control functions.

Active control is more effective since it not only reduces time required for resetting during operation, but also prevents rejects.

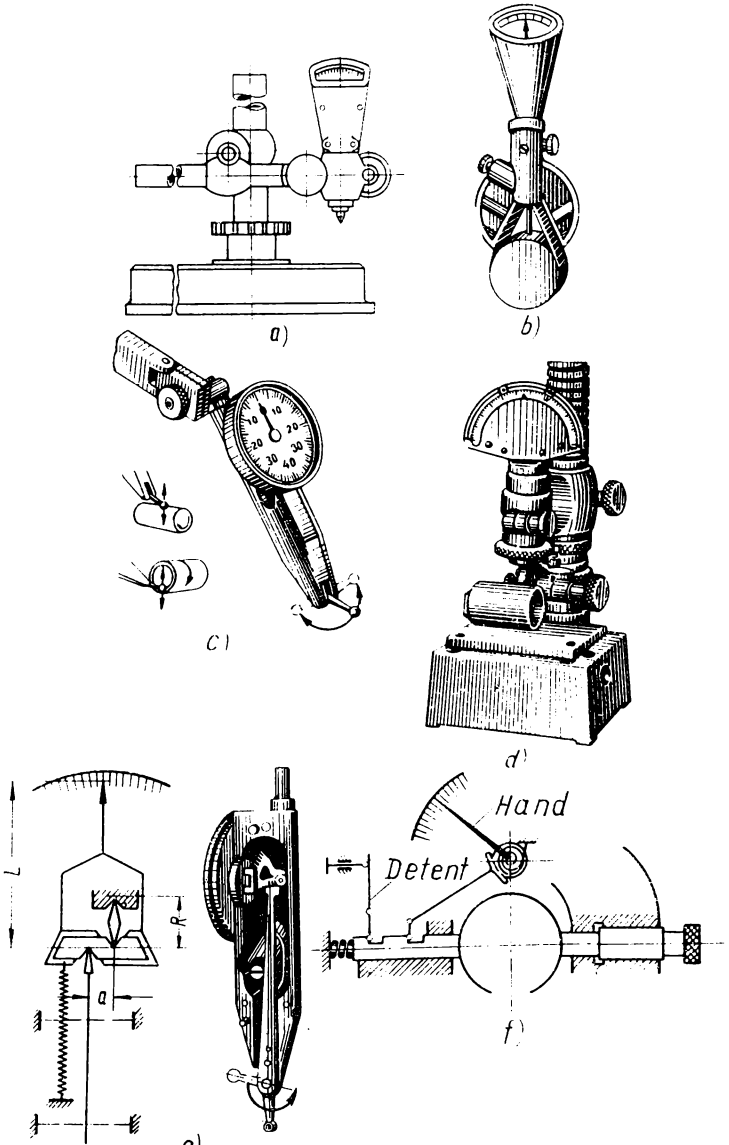


Fig. 86. Measuring instruments.

a — precision dial indicator on a universal stand, *b* — precision dial indicator arranged for outside diameter measurement, *c* — lever-and-crown-gear dial indicator, *d* — wide-scale comparator on a stand, *e* — principle of operation of a precision dial indicator (at left) and the movement of a lever-and-crown-gear dial indicator, *f* — operation of a passmeter.

Work inspection instruments for both active and passive control are gauging devices, with or without scales, linked to electrical, pneumatic, or other units. The gauging instruments check the work and are, in fact, transmitters sending work impulses to stop the machine or to reset the tool in reference to the work or to switch over the sorting mechanism.

When a finished workpiece leaves the working position it starts rolling down a chute. In its path, it passes through the gauging position. If the turned diameter is well within the specified limits, it rolls on freely. If, due to wear of the cutting edge, the machined diameter is near to the permissible upper limit, an electric contact is closed by the passing workpiece. This energises a solenoid which rotates the cross feed screw of the toolslide through a lever system and ratchet device. This feeds the slide forward a preset amount. Thus, the next workpiece will again be turned well within the specified limits and will roll unhindered to the finished work box. This will continue until the work size again approaches the upper limit and the active control system is again tripped.

Self-resetting systems sharply increase labour output and almost completely exclude spoilage.

§ 51. CUTTING SPEEDS AND FEEDS

Planning the manufacturing process is associated with the selection of the cutting conditions. This consists in determining the depth of cut *t*, the rate of feed *s* and the cutting speed *v* suitable for the given job in that the specified part accuracy and surface finish may be obtained.

The proper selection of these values is one condition providing for a maximum rate of production and minimum manufacturing costs for producing work of the specified quality.

The depth of cut is determined, in the first place, by the machining allowance. It is always more expedient to employ less passes. This reduces both machining and handling times. If a rough surface is to be turned, it will be best to remove the allowance in a single pass. High accuracy and fine surface finishes require two or more passes — roughing, semi-finishing, and finishing.

The rate of feed is selected in accordance with the depth of cut and the required quality of surface finish.

The larger the feed, the less time will be required for machining a workpiece. Therefore, the highest permissible feed must be selected that will suit the given conditions.

For definite workpiece and tool materials the cutting speed *v* is determined as a function of the depth of cut *t* and rate of feed *s*. Such important factors as the tool life and the power and speed capacities of the machine tool must also be taken into consideration.

The tool life, i. e., the time a tool will operate continuously until it becomes dulled, decreases as the cutting speed increases.

On one hand, higher cutting speeds reduce the machine time; on the other hand they are the cause of additional time losses associated with more frequent tool changing and grinding.

Both factors must be considered in selecting the cutting speed. As a rule, a tool life from 90 to 120 min of machine time is accepted for single-spindle automatics and from 180 to 240 min and even higher for multiple-spindle machines. Cutting speeds are taken from handbook data in accordance with the desired tool life. Corrections, based on previous experience, are often made in this data.

After this, a check is made to determine whether the most effective cutting speed is available on the given machine, insofar as spindle speed and required power are concerned. The power required for actual metal cutting is called *effective power.*

The effective power (N_c) required to rotate the work during the cutting process is determined from the formula:

$$N_c = \frac{P_z v}{60 \times 102} \text{ kw}, \qquad (29)$$

in which P_z is the tangential component of the cutting force, in kg;

v is the cutting speed, in m per min.

The effective power N_f required for the feed motion is calculated from the formula:

$$N_f = \frac{P_x n_s s}{1{,}000 \times 60 \times 102} \text{ kw} \qquad (30)$$

in which P_x is the feed force, in kg;

n_s is the work spindle speed, in rpm;

s is the slide feed, in mm per spindle revolution.

Table 4

Single-Point Tool Life Data

Type of automatic or semi-automatic lathe	Number of single-point tools in setup	Tool life in minutes of machine time	Number of sets of tools used per shift
Single-spindle semi-automatics	3-4	100 to 120	2 or 3
	5-7	120 to 160	2 or 3
Multiple-spindle semi-automatics	6-8	180 to 200	1 or 2
	9-12	200 to 220	1
Single-spindle automatics	5-8	160 to 180	1 or 2
Multiple-spindle automatics	10-12	200 to 240	1

Table 5

Suggested Cutting Speeds (m per min) for High-Speed Steel Tools

Workpiece material	Operations																
	Straight turning	Form turning and cutting off	Drilling	Core drilling	Reaming	Thread cutting											
						with taps						with dies					
						pitch											
						0.25	0.5	0.7	1.0	1.5	1.75	0.5	0.7	1.0	1.5	1.75	2.0
Steel 20 ($\sigma_b{}^* = 40$ to 50 kg/mm^2)	45 to 55	30 to 40	40 to 50	25 to 30	10 to 15	2.5	3.3	4.2	5.2	7.2	10.0	2.1	2.6	3.2	4.6	6.4	7.5
Steel 35 ($\sigma_b = 40$ to 60 kg/mm^2)	35 to 55	30 to 35	28 to 35	20 to 25	8 to 12	2.9	3.5	4.5	4.8	8.5	11.8	2.3	2.8	3.4	4.8	6.4	7.8
Steel 45 ($\sigma_b = 60$ to 70 kg/mm^2)	35 to 50	30 to 40	25 to 35	18 to 20	7 to 10	2.2	2.9	3.5	3.9	4.9	7.0	1.9	2.2	2.8	4.3	4.8	6.1
Free cutting steel 12	45 to 70	45 to 55	50 to 55	35 to 55	12 to 18	4.5	5.6	7.2	8.4	8.8	12.6	3.9	4.2	5.5	6.0	6.8	8.2
Free cutting steel 30	40 to 65	35 to 45	40 to 45	28 to 45	13 to 15	4.1	5.0	6.7	7.2	8.5	12.0	3.2	3.9	5.2	5.8	6.5	6.8
Stainless steel	15 to 30	10 to 12	16 to 30	10 to 15	5 to 6	1.9	2.5	3.2	4.8	5.0	5.4	1.5	1.9	2.5	3.2	4.0	—
Brass	70 to 150	70 to 150	50 to 100	45 to 80	25 to 40	6.3	8.5	10.5	12.3	17.5	20.0	5.5	6.8	7.5	8.5	10.4	10.8
Aluminium	200 to 250	200 to 250	150 to 200	60 to 80	20 to 30	7.5	10.0	13.2	14.5	19.5	22.5	6.5	7.4	8.5	9.2	10.8	11.5

Since the required power N_f for the feed motion is negligible in comparison with the power N_c for cutting, the machine tool may be selected in accordance with the power of the main drive motor (N_m) taking the power losses in the machine to be 15 to 20 per cent, i. e., with an efficiency $\eta = 0.85$ to 0.8:

$$N_c \leqslant N_m \eta. \qquad (31)$$

Machine tool service manuals usually list the work spindle speeds and the power available at each speed step of the main drive. These data enable the feasibility of the selected speeds and feeds to be checked. Table 4 indicates optimal tool life values accepted in Soviet engineering plants.

Tables 5 and 6 list cutting speeds (m per min) and feeds (mm per rev) recommended by the Leningrad Automatic Lathe Plant for machining various materials with high-speed steel tools on automatic screw machines, models 1A12—1A136. These cutting speeds may be doubled or even trebled if cemented carbide tipped tools are applied.

Table 6

Feeds for High-Speed Steel Tools, mm per rev

Material	Straight turning	Form turning and cutting off	Drilling and centring	Enlarging holes
Steel 20	0.05 to 0.18	0.02 to 0.05	0.04 to 0.14	0.10 to 0.30
Steel 35	0.05 to 0.16	0.02 to 0.045	0.04 to 0.12	0.10 to 0.25
Steel 45	0.05 to 0.15	0.015 to 0.04	0.03 to 0.10	0.08 to 0.18
Free cutting steel 12	0.06 to 0.20	0.02 to 0.06	0.04 to 0.15	0.10 to 0.35
Free cutting steel 30	0.06 to 0.19	0.02 to 0.05	0.04 to 0.12	0.10 to 0.30
Stainless steel	0.03 to 0.08	0.005 to 0.03	0.03 to 0.08	0.06 to 0.15
Brass	0.10 to 0.22	0.02 to 0.10	0.08 to 0.25	0.15 to 0.35
Aluminium	0.10 to 0.22	0.02 to 0.08	0.03 to 0.18	0.18 to 0.45

§ 52. CEMENTED CARBIDES AND HIGH-SPEED METAL CUTTING

As indicated earlier, cemented carbides applied on cutting tools enable the latter to operate normally at cutting speeds several times higher than those attainable with high-speed steel tools.

Progressive operators increase their output day by day by using the most up-to-date machining methods and the most effective procedure.

One of the most effective methods of increasing the productivity of labour is high-speed metal cutting.

Many progressive operators have proved that an inventive approach to the production capacity of a machine tool will enable cutting speeds of 2,000 and even 3,000 m per min to be successfully applied.

High cutting speeds have been employed for both single- and multiple-spindle automatic and semi-automatic lathes.

The new multiple-tool semi-automatic, model MP-5, in operation on ball bearing manufacture, uses single-point tools tipped with grade T5K10 cemented carbide to turn hard steel grade ШХ15 at cutting speeds of 125 to 150 m per min. The previous speed for turning bearing rings with high-speed steel tools was 25 to 30 m per min.

In testing new models of multiple-spindle bar and chucking machines, the cutting speed for machining steel 45 with carbide tipped tools was increased to 165 m per min with end and side toolslide speeds of 0.4 and 0.2 mm per revolution, respectively. A cutting speed of 400 to 450 m per min was achieved in testing new single-spindle semi-automatics.

V. A. Kolesov, a well-known progressive lathe operator, devised tools with a supplementary cutting edge having a zero approach angle that enabled heavy rates of feed to be employed at high cutting speeds. For example, in turning steel 45 at a speed of $v=150$ m per min and a depth of cut $t=1.7$ to 2 mm, a feed of $s=2.7$ mm per revolution was applied. This is 5 or 6 times as large as ordinary turning feeds.

Improved cutting tool and machine tool design, and more efficient shop organisation permits increases in speeds and feeds. Progressive lathe operators have shown, however, that carbide tipped tools and high speed cutting may also be expediently applied to existing machine tool equipment.

For this purpose, each machine tool must be carefully inspected and adjusted. The operation of spindle bearings and toolslide ways should be checked. The spindle should run true and excess play in all toolslides should be taken up; it is necessary to check whether tools are reliably clamped. Often, when a machine tool is to be employed for high cutting speeds, it will be found that the available work spindle speed and drive motor power are not high enough. In such cases, alterations are made to increase the speeds and power within feasible limits.

In the application of high metal-cutting speeds, it is of prime importance to reduce the handling time. This further increases the rate of production.

The workpiece is loaded and unloaded by hand in single-spindle semi-automatic lathes. It is, therefore, necessary to reduce the time required for these handling operations to a maximum extent. This can be achieved by the application of improved mechanical, electrical, or hydraulic chucking devices. Other manual operations should also be speeded up.

Much time is lost in setting up, changing, and adjusting tools in automatics and semi-automatics, as well as on other work organisation measures. This time should also be sharply reduced where possible.

This may be achieved by doing certain preparatory and auxiliary work outside of the machine, i. e., during the time the latter is in regular operation.

Toolholders are available that are designed to permit sharpened single-point tools, drills, etc., to be set up accurately beforehand. No further adjustment is required after changing the tools; the toolholder is merely clamped in the ordinary way (see Fig. 95).

Single-point tools, drills, and others are supplied to the machine in two or three full sets so that there will always be a spare set on hand during operation.

A large amount of cemented carbide tips of various grades are available in the U.S.S.R. The most suitable should be selected for each job. Most widely used grades and their applications are listed in Table 7.

Table 7

Grades of Cemented Carbide and Their Applications

Grade	Chemical content			Minimum Rockwell hardness number (scale A)	Application	
	Tungsten carbide WC	Cobalt Co	Titanium carbide TiC			
BK3	97	3	—	90	Finishing	Machining cast iron and non-ferrous alloys
BK4	96	4	—	89.5		
BK6	94	6	—	89		
BK8	92	8	—	88	Roughing	
T5K10	85	9	6	88.5	For roughing and cutting off	Machining steel
T15K6	79	6	15	90	For semi-finishing	
T30K4	66	4	30	91	For finish and precision turning	
T14K8	78	8	14	89		
T15K6T	79	6	15	90		
T60K6	34	6	60	92		

The form and cutting angles of carbide tipped single-point tools used on automatics and semi-automatics are the same as for tools used in ordinary engine lathes.

The design of carbide tipped single-point tools is illustrated in Fig. 84.

The successful application of carbide tipped tools will require their careful manufacture. Most important factors, in this connection, are reliable brazing or clamping of the tips and correct grinding and lapping of the cutting edges.

New ceramic tool materials, made chiefly of aluminium oxide, were invented by Soviet scientists and are being more and more extensively used on lathes.

Of these materials, grade ЦМ-332 retains its cutting capacity at temperatures up to 1 200°C.

Examples of the application of ceramic tool materials are given in Table 8 for finish turning and in Table 9 for rough turning operations.

Table 8

Finish Turning Data for Ceramic Tool Material, Grade ЦМ-332

Material turned	Cutting conditions			Class of surface finish	Class of accuracy	Tool life, min
	depth of cut, mm	feed, mm/rev	cutting speed, m/min			
Steel 40X	0.5 to 0.7	0.1 to 0.2	200 to 220	7	2	120
Steel OXM	0.4 to 0.45	0.1	300 to 400	7	2	40
Steel 40XФA	1.0	0.07	604	7	2	70
C. I. СЧ22-44	0.5	0.07	235	7	2	90
C. I. СЧ21-40	1.0	0.05	157	7	2	20

Table 9

Rough Turning Data for Ceramic Tool Material, Grade ЦМ-332

Material turned	Cutting conditions			Tool life, min
	depth of cut, mm	feed, mm/rev	cutting speed, m/min	
Steel 40X	10.0	0.33	319	50
Steel 20X2H4A	3.0	0.28	382	60
Steel 45	4.0	0.5	221	80
C. I. СЧ12-48	10.0	0.33	352	90
C. I. СЧ15-32	7.0	0.45	362	60

CHAPTER II

SETTING UP AUTOMATICS AND SEMI-AUTOMATICS. GENERAL INSTRUCTIONS

§ 53. ELEMENTS OF PREPARATORY AND SETTING-UP OPERATIONS

Setting up a machine tool involves all preparation required for machining a workpiece in accordance with the accepted manufacturing process, to the specified accuracy and at a maximum rate of production.

Before setting up, it will be necessary to select the type of blank to be used and to plan the manufacturing process. Then a tooling layout and cyclogram are drawn up on the basis of the manufacturing process and the time is calculated for each machine movement within the operating cycle.

Standard cutting tools, attachments, gauges and cams are selected on the basis of the tooling layout (Table 10) and the cyclogram (see Figs. 68 and 69). All special tooling is then designed and manufactured.

When all of this preparatory work has been completed, the setup man proceeds to set up the machine tool.

The machining process is broken down into separate operation elements so as to ensure the production of high quality work at a maximum rate of production and at minimum cost.

Since the manufacturing process may be designed in various ways, even on the same machine tool, the processing break-down between the various cutting tools must be checked several times to select the most expedient method.

The following main rules should be followed in planning a manufacturing process, i. e., in laying out the sequence of operations necessary to produce a piece of work:

1. Overlap working operations wherever possible and try to increase the number of tools operating simultaneously.
2. Overlap handling operations with each other and with the working operations.
3. Overlap roughing and finishing cuts only in cases when this does not have a detrimental effect on the quality of the workpiece. Finish machining should be done at the end whenever possible.
4. Arrange the cutting tools so as to counterbalance the cutting forces to a maximum extent.
5. Provide for a finish cut over the full length of a surface if it was roughed in sections by several tools.
6. Do not permit substantial reduction in the rigidity of the workpiece (cutting deep grooves) until all the machining is completed. This is especially important in thread cutting.
7. Turn precise form surfaces in two cuts whenever possible.

8. Provide a dwell (stop) during 5 to 10 spindle revolutions at the end of the cross slide travel. This will considerably improve the surface finish.

9. Spot (centre) drill before drilling small diameter holes.

10. In drilling deep holes, pull out the drill several times (withdraw it clear of the hole) to break up and remove chips and to facilitate drill cooling.

11. In drilling a stepped hole, first drill the largest diameter and then the next smaller diameters in order. This will decrease the total travel required by all the drills.

12. For multiple-spindle automatics and progressive-action automatics, the machining should be distributed between the positions so that the time required at each position is the same.

13. Break down the longest single (limiting) operation so that it will be performed in two or even three positions if this is not detrimental to the quality.

14. Finish machine external and internal surfaces at a single position to obtain their strict alignment.

15. Exclude interference between holders and tools operating either simultaneously or consecutively.

The tooling layout and operation sheet are the principal guide for the setup man. They should include all data concerning the blank or stock, cutting tools, toolholders, cutting speeds and feeds, depths of cut, slide travel, initial positions of operative elements, rate of production, etc.

Tooling layouts are drawn full size for medium-size work. Small diameter work (up to 10 mm) or large diameter work (over 50 mm) will require some scale to be used such as 2 to 1 or 5 to 1 in the first case and 1 to 2 or 1 to 5 in the second.

A number of additional factors, depending on the type of machine, its principle of operation, design and even its size, must also be given due consideration in planning the sequence of operations and designing the tooling layout.

§ 54. TOOLING LAYOUT AND OPERATION SHEET FOR AUTOMATIC SCREW MACHINES

A tooling layout and operation sheet for a single-spindle automatic screw machine is illustrated in Table 10. It is designed for turning a part, called a head, of 36 mm round bar stock, of steel A12.

These automatics possess camshafts and auxiliary shafts. The operating cycle is completed during one revolution of the camshaft which rotates at a preset speed that is constant for the given setup (see Fig. 64).

The tooling layout contains sketches of the work in the various stages of machining, by operation elements. The required cutting tools are indicated and are shown at the end of the feed motion. The form of the turret-operating cam is also shown.

The operation sheet has a sketch of the finished workpiece. It indicates the material of which the workpiece is to be made and lists the operation elements in the proper sequence and in accordance with the tooling layout.

To fill in the operation sheet, it will be necessary to select the cutting speeds and feeds and to calculate the lengths of travel of all the tools in each operation element.

In selecting the cutting speed and feed for each tool, it must be noted that the spindle speed is the same for two tools operating simultaneously and is determined by the maximum permissible cutting speed on the largest diameter machined in the given operation element.

Cutting tools, mounted on the same slide and operating simultaneously, will always have the same rate of feed which is determined by the tool permitting the munimum feed.

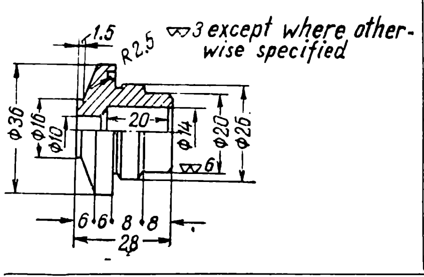
These rules may be checked on the operation sheet given in Table 10.

On the basis of plant data and standards (Table 6), the feed can be selected for rough form turning with cross-cutting tools equal to 0.04 mm per spindle revolution, for finish forming equal to 0.025 mm per revolution and for straight turning and drilling equal to 0.12 mm per revolution. By selecting a cutting speed of 68 m per min for form turning the external surfaces in the second operation element, from two different cross slides, and establishing the corresponding spindle speed $n_s = 600$ rpm, the cutting speed for the 14 mm drill is also determined. The drill is clamped in the turret.

In the fourth operation element, a combination toolholder, mounted in a turret hole, carries two tools—one for cutting the face groove and the other for the external chamfer. They operate simultaneously and, consequently, at the same rate of feed. On the other hand, the feeds of the front and back slides and the turret are not dependent on each other in the second operation element and may be different. Cutting speeds and feeds are determined in the following order:

1. Speeds are selected to suit the processing factors (surface finish required, rigidity of the work, machining allowance, etc.) from tables furnished with the automatics (usually included in the Service Manual).
2. The cutting speed is determined on the basis of the selected feed and given depth of cut. The cutting speeds must provide for a tool life of at least 120 minutes for simple tools and at least 240 minutes for complex tools. The selected cutting speed must then be compared to that used under similar conditions by progressive lathe operators working on the same types of automatics or semi-automatics. This may reveal the possibility of applying higher speeds and thereby increasing the rate of production.

Operation Sheet for the Automatic Screw Machine, Model 1136

 1.5 R2.5 3 except where otherwise specified Φ36 Φ16 Φ10 20 Φ14 Φ20 Φ26 6 6 6 8 8 28	Part name—head	Material: free-cutting steel A12 Round bar stock 36 mm
	Spindle speed, rpm — n_s Cutting speed, m/min — v	Turning $n_s=600$ rpm, $v=68$ m/min Turning $n_s=1{,}500$ rpm, $v=94$ m/min
	Total spindle revolutions to make one piece — 440	Seconds to make one piece — 44
	Gross production $Q'_g=82$ pcs/hr	Actual production (15% losses) $Q'_a=82\times0.85=70$ pcs/hr

Operative unit	Order of operation elements	Travel *l*, mm (cam throw)	Feed *s*, mm/rev	Spindle revolutions required for each operation element	Accepted for calculations		Number of hundredths on cam	Hundredths on cam for			
					working travel	idle motions		calculating production		cam design	
					spindle revolutions	hundredths on cam		start	finish	start	finish
1	2	3	4	5	6	7	8	9	10	11	12
Turret	1. Feed stock to stop	—	—	—	—	2.5	2.5	0	2.5	0	2.5
	2. Index turret. Drill 14 mm	— 22	— 0.12	— 184	— 184	1.5 —	1.5 42	2.5 4	4 46	2.5 4	4 46

(Continued)

Operative unit	Order of operation elements	Travel l, mm (cam throw)	Feed s, mm/rev	Spindle revolutions required for each operation element	Accepted for calculations		Number of hundredths on cam	Hundredths on cam for			
					working travel	idle motions		calculating production		cam design	
					spindle revolutions	hundredths on cam		start	finish	start	finish
1	2	3	4	5	6	7	8	9	10	11	12
Turret	3. Index turret. Chamfer hole	— 2.0	— **0.12**	— 17	— 17	1.5 —	1.5 4	46 47.5	47.5 51.5	46 47.5	47.5 51.5
	4. Index turret. Cut groove and external chamfer	— 3.0	— 0.04	— 75	— 75	1.5 —	1.5 17	51.5 53	53 70	51.5 53	53 70
	5. Index turret Finish turn diam 20 mm, $n_s = 1{,}500$ rpm } advance } return	— 8 8	— 0.12 0.36	— 66 22	— 26* 9*	1.5 — —	1.5 6 2	70 71.5 77.5	71.5 77.5 79.5	70 71.5 77.5	71.5 77.5 79.5
	6. Index turret Drill 10 mm, $n_s - 1{,}500$ rpm Index turret	— 10 —	— 0.12 —	— 84 —	— 34* —	3 — —	3 7.5 3	79.5 82.5 —	82.5 90 —	79.5 82.5 90	82.5 90 93
Cross slides	2, 3. Front slide. Form diam 36 to 20.4	7 1	0.04 0.025	175 40	— —	— —	40 9	— —	— —	4 44	44 53

10 440

Cross slides	2, 3, 4. Back slide. Form diam 36 to 16		11	0.04	275	—	—	63	—	—	6	69
		Diam										
	7. Vertical slide. Cut of $n_s=1{,}500$ rpm	16 to 12	2	0.06	33	14*	—	3	90	93	90	93
		12 to 10	1	0.04	25	10*	—	2.5	93	95.5	93	95.5
		10 to 8	2	0.12	17	7*	—	1.5	95.5	97	95.5	97
	Withdraw cut-off tool		—	—	—	—	3	3	97	100	97	100

Total number of spindle revolutions for working travel $n_w=376$.

Number of hundredths for idle motions $K_i=14.5$.

Number of hundredths for working travel $K_w=(100-14.5)=85.5$.

Number of spindle revolutions to make one piece: $n_{cycle}=\dfrac{376\times100}{85.5}=440$ revolutions.

Cycle time (seconds to make one piece): $T_c=\dfrac{60\times440}{600}=44$ sec.

Gross production: $Q'_g=\dfrac{60\times60}{44}=82$ pcs/hr.

Actual production (15% losses): $Q'_a=82\times0.85=70$ pcs/hr.

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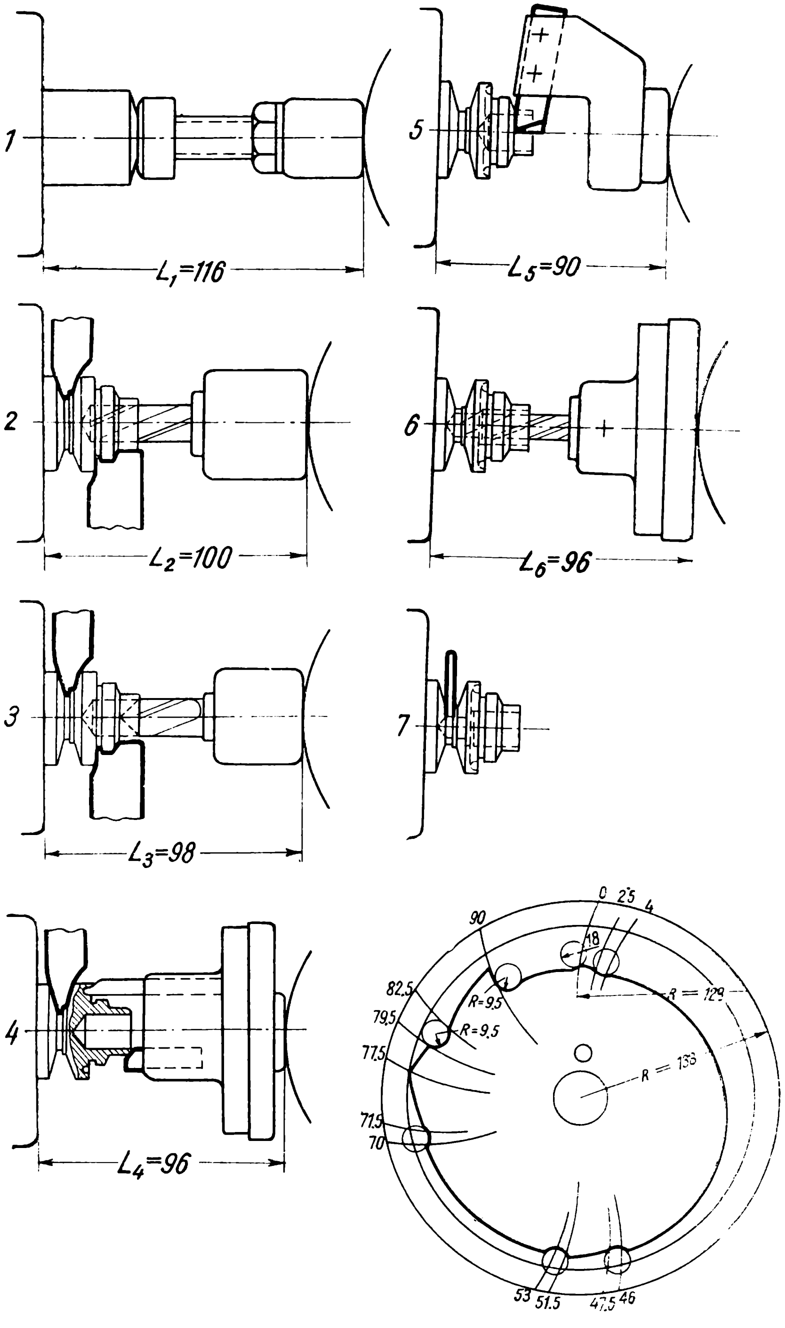
* After multiplying by the equivalent revolutions factor.

TOOLING LAYOUT FOR TABLE 19



The spindle speed is then determined by substituting the selected cutting speed in the well-known formula

$$n_{s_1}=\frac{1{,}000v}{\pi d}\text{ rpm}$$

or by employing a speed chart (see Figs. 26 and 27) furnished with the machine.

The nearest values of available spindle speeds are then selected from a table of speed steps and the corresponding change gears are installed in the main drive of the automatic.

If different spindle speeds may be obtained in the operating cycle, the second spindle speed and corresponding cutting speed is established for the same set of change gears.

In our example, the second cutting speed equals 94 m per min and the corresponding spindle speed is 1,500 rpm.

These data will be sufficient to fill in the upper part of the operation sheet as well as columns 1 and 2.

The next step is to determine the travel of the cutting tools required in each operation element. This is done on the basis of the part drawing and the values are set down in column 3. A rule to be followed in determining travel of each tool is to add from 0.5 to 3 mm (in accordance with the size of the automatic and the slide travel) to the required tool travel determined from the dimensions of the part drawing. This will prevent the tool from cutting into the work during its rapid approach movement.

To comply with this rule, the following tool travel values have been set down in column 3 of the operation sheet (Table 10):

operation element 2—22 mm instead of 20 mm on the drawing,
operation element 3—2 mm instead of 1.5 mm on the drawing,
operation element 4—$2.5+0.5=3$ mm instead of 2.5 mm on the drawing, etc.

The feeds selected for each operation element are set down in column 4 in mm per spindle revolution.

§ 55. TIME REQUIRED FOR EACH OPERATION ELEMENT

The time required for an operation element depends on: 1) tool travel, 2) selected rate of feed, 3) number of spindle revolutions required for the tool travel, and 4) comparison of the number of spindle revolutions with the spindle speed in rpm.

The number of spindle revolutions for each operation element is determined by the formula:

$$n_o=\frac{l}{s}\text{ revolutions,}\qquad(32)$$

in which l is the tool travel in mm,
s is the rate of feed in mm per revolution.

Therefore, to fill in column 5, it will be necessary to divide the value l, of column 3, by the feed s indicated in column 4.

After determining the number of spindle revolutions n_o for the given operation element, the time required t_0 is determined by dividing n_0 by the spindle speed n_s. The quotient will be the time in minutes:

$$t_o=\frac{n_o}{n_s}\text{ min} \tag{33}$$

or in seconds:

$$t'_o=\frac{60n_o}{n_s}\text{ sec.} \tag{33'}$$

It will be more convenient to determine the time required for each operation element by substituting the equation $n_0=\frac{l}{s}$ into the preceding formulas:

$$t_o=\frac{l}{n_s s}\text{ min} \tag{34}$$

and

$$t'_o=\frac{60l}{n_s s'}\text{ sec,} \tag{34'}$$

in which n_s is the spindle speed in rpm.

These values may also be determined from an alignment chart devised for this machine (Fig. 239).

The total time in seconds is based on the total number of spindle revolutions to complete a piece if the spindle runs continuously at one speed. If, in different operation elements, different spindle speeds are employed, it will be necessary to recalculate the number of spindle revolutions in each operation element to a single basis, dividing by the so-called *equivalent revolutions factor.*

If, as shown in the operation sheet of Table 10, the work is machined with spindle speeds of:

$$n_{s_1}=600\text{ rpm and }n_{s_2}=1{,}500\text{ rpm},$$

then, at the same rate of feed, machining at 1,500 rpm will be $\frac{1{,}500}{600}=2.5$ times faster than at a speed of 600 rpm.

This means that the time required for each spindle revolution at $n_{s_1}=600$ rpm will be the same as that required for 2.5 revolutions at $n_{s_2}=1{,}500$ rpm.

The ratio of the higher to the lower speed in rpm is called the equivalent revolutions factor.

This factor is used in calculating the cycle time and in laying out the cams.

For example, in the fifth and sixth operation elements, performed from the turret and in the seventh operation element from the vertical slide, comparable results may be obtained in calculating n_o for these cases (column 6) by dividing the value of column 5 by the equivalent revolutions factor 2.5.

Only those numbers of revolutions are carried over from column 5 to 6 that refer to operation elements that do not overlap. Thus machining, performed from the cross slides and overlapped by turret tool operation, is crossed through in column 6.

The total number of spindle revolutions n_w, required for all working travel that is not overlapped, is then determined. In the example of Table 10, $n_w=376$ revolutions.

It will be evident from further explanation that there is no need to calculate the time required for each operation element; it will be sufficient to calculate the total number of spindle revolutions required for all working travel.

§ 56. TIME REQUIRED FOR IDLE MOTIONS AND WORKING TRAVEL

The time required for idle motions depends on the design and type of automatic being employed; in certain types, the idle motion time is constant and is in no way dependent on the workpiece.

In other automatics the idle motion time is variable and is a function of the cycle time.

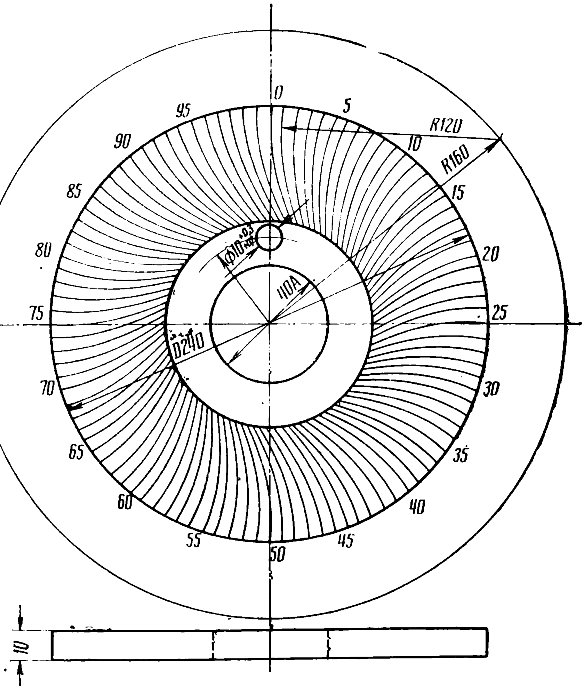


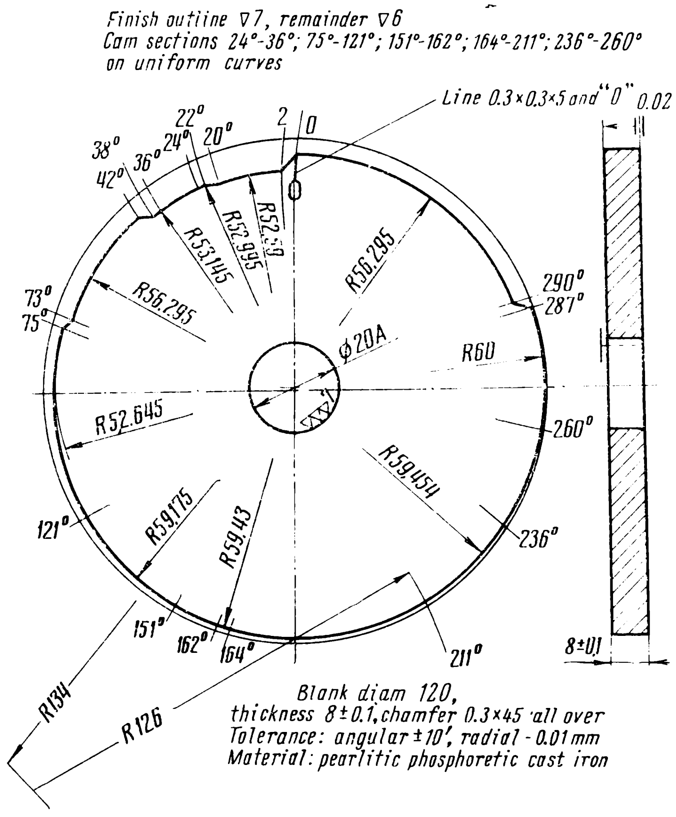
Fig. 87. Dividing the plate cam of the model 1A136 automatic into hundredths.

The idle motion time (t_i) is determined from tables given in the setting-up instructions of each automatic.

In the automatic screw machine used in the example of Table 10, the idle motion time depends on the workpiece and is to be taken from tables (for the given automatic) in accordance with the cycle time.

One workpiece is produced to each revolution of the camshaft, i. e., in one cycle, in automatics controlled by a camshaft. Therefore, each working or idle movement takes place during a definite part of the camshaft revolution. To establish an interconnection between the times required for each movement and to calculate the cycle time, the surfaces of the cams on the camshaft are divided into an equal number of small parts (Fig. 87).

Cams are usually divided into either 100 or 360 parts and the time required for each working or idle movement is expressed in either hundredths or in degrees (since there are 360° in a full circle) (Fig. 88).



Finish outline ∇7, remainder ∇6
Cam sections 24°-36°; 75°-121°; 151°-162°; 164°-211°; 236°-260° on uniform curves

Blank diam 120,
thickness 8±0.1, chamfer 0.3×45 all over
Tolerance: angular ±10′, radial - 0.01 mm
Material: pearlitic phosphoretic cast iron

Fig. 88. Dividing a plate cam into degrees and laying out lobes for automatics, models 1A10П, 1П12 and others.

The time required for the idle movements may be determined by estimating the approximate time for the whole cycle. This is done on the basis of the working travel. The total time required for the latter is increased by 25 or 30 per cent, i. e., it is multiplied by 1.25 or 1.3. Then, the time required for the idle movements is taken from tables in accordance with the estimated cycle time and, when this has been done, the cycle time can be computed exactly.

The number of hundredths of cam surface required for unoverlapped movements, such as feeding the stock to the stop, chucking, and turret indexing, is determined from the tables for the model 1136 automatic and is set down in column 7. Three hundredths should be reserved, as a rule, for withdrawal of the cut-off tool.

All the hundredths required for unoverlapped idle movements (K_i) will sum up to 15.5 hundredths (see Table 10).

The next step is to determine the number of hundredths of cam surface required for the total working travel and for each working movement. The number of hundredths remaining after idle movements are performed is first calculated. In our example, these hundredths (K_w) will equal $100-15.5=84.5$. Then the number of hundredths for each working travel is calculated. This is done by dividing the number of spindle revolutions n_0, set down in column 6 for each operation element, by the number of revolutions to one hundredth (n_h). The results are set down in column 8. The hundredths required for the idle movements are carried over to this column as well.

Therefore, to determine the time required for the working and idle movements, expressed in hundredths of cam surface:

1. Estimate the approximate cycle time.

2. Find, in the tables, the number of hundredths (K_i) required for the idle movements, on the basis of the estimated (approximate) cycle time T_a. The latter is estimated as equal to 1.25 to 1.3 multiplied by the time required for all working travel, i. e., $T_a=(1.25 \text{ to } 1.3)\frac{60n_w}{n_s}$ seconds.

3. Determine the number of hundredths for the total working travel:

$$K_w=(100-K_i) \text{ hundredths.} \qquad (35)$$

4. Determine the number of spindle revolutions (n_{cycle}) for the whole cycle:

$$n_{cycle}=\frac{n_w \times 100}{100-K_i}=\frac{n_w \times 100}{K_w} \text{ rev per cycle.} \qquad (36)$$

5. Calculate the number of spindle revolutions (n_h) for each hundredth:

$$n_h=\frac{n_{cycle}}{100} \text{ spindle rev per hundredth.} \qquad (37)$$

6. Determine the number of hundredths K_{o_1}, K_{o_2}, etc., required for each operation element (1, 2, etc.):

$$K_{o_1}=\frac{n_{o_1}}{n_h} \text{ hundredths: } K_{o_2}=\frac{n_{o_2}}{n_h} \text{ hundredths} \qquad (38)$$

in which n_{o_1}, n_{o_2}, etc., the number of spindle revolutions required for the first, second, etc., operation elements (column 5, Table 10).

§ 57. CYCLE TIME AND RATE OF PRODUCTION OF AUTOMATICS

The total number of spindle revolutions for the unoverlapped working travel in the example of Table 10 will be $n_w=376$. The number of hundredths indicated in the tables of the model 1136 automatic for idle movements will sum up to $K_i=14.5$. This will have the following number of hundredths for the total working travel:

$$K_w=100-K_i=100-14.5=85.5 \text{ hundredths.}$$

During these 85.5 hundredths, the spindle must make 376 revolutions. Therefore, in one cycle, i. e., in one revolution of the camshaft, corresponding to the production of one workpiece, the spindle must make n_{cycle} revolutions as determined from formula (36):

$$n_{cycle}=\frac{376\times100}{100-K_i}=\frac{376\times100}{85.5}\approx 440 \text{ spindle revolutions.}$$

The number of spindle revolutions corresponding to each hundredth can be easily calculated from the preceding by formula (37):

$$n_h=\frac{440}{100}=4.4 \text{ spindle revolutions per hundredth.}$$

The number of hundredths for each operation element can next be calculated. For example, for the second operation element of Table 10:

$$K_{o_2}=\frac{184}{4.4}\approx 42 \text{ hundredths.}$$

The cycle time T_c can be calculated from the formula:

$$T_c=\frac{n_{cycle}}{n_s} \text{ min or } T'_c=\frac{60\times n_{cycle}}{n_s} \text{ seconds} \qquad (39)$$

in which n_s is the spindle speed in rpm.

In the example of Table 10, the cycle time will be:

$$T'_c=\frac{60\times n_{cycle}}{n_s}=\frac{60\times440}{600}=44 \text{ sec.}$$

The rate of production, i. e., the number of pieces produced in a unit of time (minute, hour, or shift), can be calculated from the cycle time.

First, the gross production is calculated. It does not take into consideration time losses due to tool adjustment and other measures associated with stopping the machine, assuming that operation is continuous.

The gross rate of production is determined by means of formula (23) or (24):

$$Q_g=\frac{1}{T_c}=\frac{60}{T'_c} \text{ pcs per min.}$$

$$Q'_g=\frac{60\times 60}{T'_c}=\text{pcs per hr.}$$

The gross production is calculated in Table 10:

$$Q'_g=\frac{60\times 60}{44}\approx 82 \text{ pcs per hr.}$$

The actual or net production Q'_a, in which all losses have been accounted for, is determined from the formula

$$Q'_a=Q'_g\eta \text{ pcs per hr} \qquad (40)$$

in which η is the utilisation factor of the machine tool. The value of η varies from 0.8 to 0.95. The more complex the machine tool and workpiece, the nearer η will approach 0.8.

In the example, η may be taken as 0.85; the actual production will then be:

$$Q'_a=82\times 0.85=70 \text{ pcs per hr.}$$

§ 58. DETERMINING THE PROPER SEQUENCE OF THE WORKING AND IDLE MOVEMENTS IN HUNDREDTHS

The sequence of the working and idle movements in hundredths is determined on the basis of: 1) the tooling layout, 2) the order of the operation elements set down in the operation sheet (column 2), 3) overlapping of working and idle movements (column 7), and 4) the number of hundredths required for each movement (column 8).

The sequence of the movements is set down in columns 9 and 10 in accordance with the data of column 8.

For example:

operation element *1*—feed stock to stop—hundredths from 0 to 2.5;
operation element *2*—index turret—hundredths from 2.5 to 4;
drill 14 mm—hundredths from 4 to 46.

An examination of the figures in columns 9 and 10 will show that they are the numbers of the hundredths (counting from the beginning) with which an unoverlapped movement starts (column 9) and finishes (column 10).

For this reason, the first movement in the cycle (feed stock to stop) begins with the 0 hundredth on the cam and the last movement (withdraw cut-off tool) ends with the 100 hundredth or a full circle. The latter will, of course, coincide with the 0 hundredth. The withdrawal of the cut-off tool is the end of the machining operation. The cut-off operation cannot be overlapped by other operation elements.

A careful analysis of the data set down in columns 11 and 12 and a comparison with columns 9 and 10 shows that the beginning and end of the movements of the operative units (turret, slides, etc.) are set down in these last two columns. These data are required in drawing and making the cams.

§ 59. DETERMINING RADII OF PLATE CAM CURVES

The radii of plate cam curves in laying out a cam are determined in the following order (Table 10):

1. The main data on the cam and the drive of the operative unit are taken from the service manual. They include: a) maximum radius of the cam R_{max}, b) minimum radius of the cam R_{min}, c) height of the cam lever fulcrum above the cam centre, and d) ratio of the lever system.

2. The surface of the plate cam is divided into 100 equal parts (hundredths).

3. The cam radii are determined for each operation element from the final position of the operative element.

4. For end-working slides, the maximum diameter of the cam corresponds to a slide position at the minimum distance from the spindle nose. For cross slides, R_{max} corresponds to the position where the tool has advanced slightly beyond the spindle axis (see also Fig. 88).

This type of data, for the turret, for example, is always indicated in the tooling layout. In Table 10, $R_{max}=120$ mm. This corresponds to the final position of the turret in the fifth position where $L_5=L_{min}=$ $=90$ mm.

5. The other radii R for the final positions of the units are determined as the differences between R_{max} and the other values L, i. e., according to the formulas:

$$R_1=R_{max}-(L_1-L_{min})=(R_{max}+L_{min}-L_1); \qquad (41)$$

$$R_2=R_{max}-(L_2-L_{min})=(R_{max}+L_{min}-L_2), \text{ etc.} \qquad (41')$$

In our example:

In position 1: $R_1=120+90-116=94$ mm;
" 2: $R_2=120+90-100=110$ mm;
" 3: $R_3=120+90-98=112$ mm, etc.

6. The cam radius at the beginning of working travel (in each case) is calculated by subtracting the travel of the cutting tool, as set down

in column 3, from the radius at the end of each corresponding travel (under the condition that the lever system has a 1 to 1 ratio).

In our example:

In position 2: $R'_2 = 100 - 22 = 78$ mm;

In position 3: $R'_3 = 112 - 2 = 110$ mm, etc.

Usually the travel values of all working movements are increased by 0.5 to 2 mm, i. e., the cam radii R' are reduced by 0.5 to 2 mm. This enables the tool to approach the work at slow feed and not "jab in" at the start of the cut.

7. After determining the beginning and end radii of the cam lobes for each operation element, we are ready to draw the cam.

§ 60. DESIGNING PLATE CAMS

The following factors are to be taken into consideration in designing plate cams:

1. The movement of an operative unit (slide, turret) usually consists of a rapid approach, working feed and rapid return.

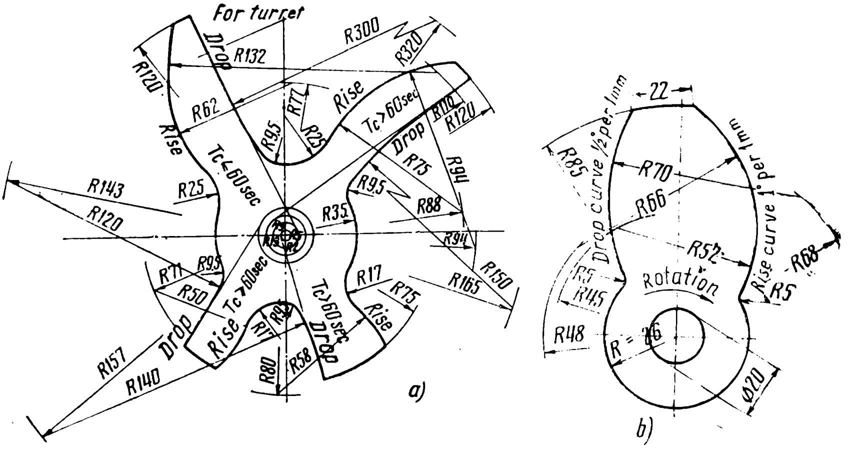


Fig. 89. Cam templates for drawing curves of rapid traverse movements on plate cams.

a—for automatic screw machines, models 1A124-1A136, b—for precision Swiss-type automatic screw machine, model 1A10П (headstock and rocker arm cams).

2. Rapid approach and return should be performed with minimum time loss. Therefore, the cam curves should rise or drop sharply at these places. Curves for rapid approach and return are drawn to a special template (Fig. 89) in accordance with the cycle time.

3. The working feed curve should provide for motion at a constant speed, i. e., at a uniform rate of feed. This can be achieved if the roll

riding the cam rises equal amounts in equal angles of cam rotation, i. e., if the roll travels along a uniform curve (the so-called Archimedean spiral). In this curve, the radius increment is proportional to the increment of rotation angle.

This property of a uniform curve may be expressed by the equation:

$$r_{vector}=K\theta \tag{42}$$

in which r is the radius of the uniform curve;
θ is the angle of rotation of the cam;
K is a constant for the given uniform curve.

4. A uniform curve (Fig. 90) is developed by drawing the cam full size and dividing its circumference into hundredths. The lines of the hundredths are drawn along arcs having a radius equal to that of the cam roll lever (see Fig. 87). The beginnings and ends of the working travel lobes are marked off on the corresponding divisions (hundredths) by swinging arcs of the required radii (see Fig. 88). Then the cam roll is drawn full size, tangent to the above points (Fig. 90). Besides this, on the line (division) for the end of the travel, the roll is drawn in its position at the beginning of the working travel for the given lobe. The distance between the two roll positions on the hundredth division (arc) for the end of travel is divided into as many equal parts as there are hundredths in the given working movement. The intersections of the arcs (Arabian numbers) with the corresponding hundredths (Roman numerals) will be the points of tangency of the roll in these positions (2 — II, 3 — III, etc.). These points will describe a curve which will ensure a uniform feed of the operative unit equal to the required value.

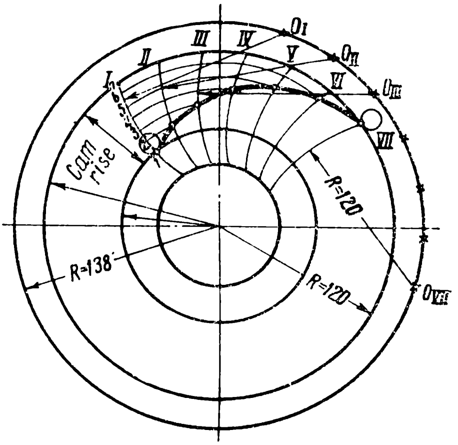


Fig. 90. Developing a uniform cam lobe curve.

The uniform curves on the cam lobes are usually milled with an end mill of the same diameter as the cam roll.

The cam is mounted on a dividing head in which the spindle is linked to the table travel screw of the milling machine. To set up this machine it will be necessary to calculate the lead H of the uniform curve, i. e., the rise of the curve in one full revolution:

$$H=\frac{h\times 100}{K}\text{ mm} \tag{43}$$

or

$$H=\frac{h}{\alpha}\times 360 \text{ mm} \qquad (43')$$

in which h is the required rise on the cam lobe in mm;

K is the number of hundredths occupied by the given lobe (working movement);

α is the angle in degrees of the given lobe.

A complex cycle of movements is frequently employed for automatics. It may include rapid approach, first working feed, second working feed of smaller magnitude, dwell (the unit stops for a certain time without feed, usually from 5 to 10 spindle revolutions), and rapid return. This cam lobe will have three sections for the working movement: the first corresponds to the first feed and is a uniform curve with a given rise, the second corresponds to the second feed and is a uniform curve with a smaller rise, while the third is the dwell. The latter has no rise and is described along a circle.

Thread cutting is usually performed on automatics by taps or dies. The cam which feeds the unit with the tool for thread cutting does not have to provide for the pitch of the thread being cut since the tool itself screws on or into the work as a nut or bolt would. *As a rule, the cam lobe for thread cutting is drawn so as to obtain slide movement 5 to 10 per cent less than the thread pitch*, i. e., it lags behind the theoretical curve. The curve on the cam lobe for the "running off" of the die or the "running out" of the tap is drawn in the same manner as the threading curve. If the tool return curve had the same form in threading as for other rapid return movements, the thread would be stripped and the tool broken.

Tool withdrawal in thread rolling should also be performed at the working feed and, therefore, the return curve on the lobe should follow a uniform curve.

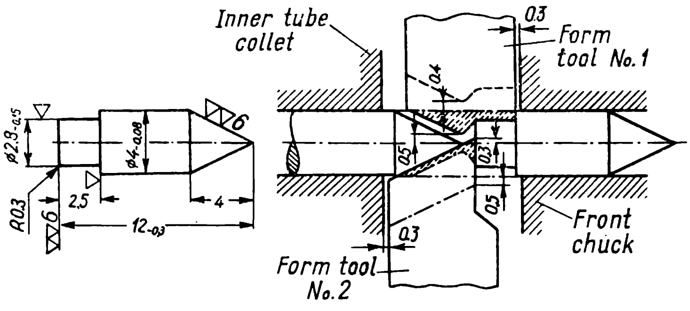
§ 61. TOOLING LAYOUT AND OPERATION SHEET FOR AUTOMATIC CUTTING OFF MACHINES

A tooling layout and operation sheet for turning a special centre on the automatic cutting off machine, model 1106, are illustrated in Table 11. In this automatic, the camshaft operates at a constant preset speed. In the first movement, the wire stock 4 mm in diameter, is fed out a distance equal to the part length (12 mm) plus 0.8 mm for cutting off.

Form tools No.1 and No.2 are fed simultaneously, but tool No. 1 leads by approximately 0.1 mm and, therefore, removes the major part of the stock in turning the taper and finishes the cylindrical surface, diam $2.8_{-0.15}$. Form tool No. 2 finish turns the taper and cuts off the finished centre. The point of this tool passes beyond the work centre by 0.3 mm.

Table 11

Tooling Layout and Operation Sheet for the Automatic Cutting-Off Machine, Model 1106



Part name: centre	Material: steel 45 (wire in coil)
Cutting speed $v=44$ m/min	Spindle speed $n_s=3{,}500$ rpm
Diameter of motor change pulley 270 mm	Camshaft change gears A:B=43:29
Total spindle revolutions to make one piece $n_{cycle}=118$ revolutions	Seconds to make one piece $T_0=2.02$ sec
Gross production $Q_g=29.7$ pcs/min	Actual production $Q_a=28$ pcs/min

Order of operation elements	Travel l, mm	Feed s, mm/rev	Spindle revolutions required, n_0	Spindle revolutions accepted for cycle calculation	Degrees of camshaft rotation			Consecutive degrees of camshaft rotation	
					Required	After deducting overlapped motions			
						idle motions	working travel	start	finish
Feed stock	12.8	—	—	—	30	30	—	0	30
Chucking	—	—	—	—	10	10	—	30	40
Straightening stock	12.8	—	—	—	100	—	—	100	200
Tool No. 1. Approach	0.4	0.035	11.4	—	35	—	—	40	75
Feed	1.5	0.035	43	—	130	—	—	75	205
Withdrawal	1.9	—	—	—	135	—	—	205	340
Tool No. 2. Approach	0.5	0.035	14	14	42	—	42	40	82
1st feed	2.0	0.035	57	57	173	—	173	82	255
2nd feed	0.3	0.012	25	25	76	—	76	255	331
Dwell	—	—	—	4	12	—	12	331	343
Withdrawal	2.8	—	—	—	17	17	—	343	360
Chuck release	—	—	—	—	10	—	—	350	360
			$n_w=100$			57	303	0	360

The following data are used to calculate the cycle time and to set up the machine: about 30° of camshaft rotation is required for stock feed, about 10° for chucking and about 17° for withdrawing the cutting tools.

This will sum up to approximately 57° for idle movements ($K_i = 57$). Therefore, the amount remaining for working movements will be $K_w = 360° - 57° = 303°$ of camshaft rotation.

Further calculations of the setup chart (operation sheet) will be similar to those given in § 56. The only difference is that the cycle is divided, not into 100, but into 360 equal parts, each corresponding to one degree of camshaft rotation. The number of tool head revolutions required for each unoverlapped operation element is calculated from the formula $n_o = \frac{l}{s}$. These values are added together to obtain the total number of spindle revolutions n_w for all unoverlapped working movements. This total number of spindle (and tool head) revolutions is to occupy the 303° of camshaft rotation mentioned above. The whole cycle occupies one full revolution (360°) of camshaft rotation. The number of tool head revolutions n_{cycle} required to make on piece, i. e., during one revolution of the camshaft:

303° corresponds to n_w;

360° corresponds to n_{cycle}

therefore $n_{cycle} = \frac{n_w \times 360}{303}$ revolutions

or $n_{cycle} = \frac{100 \times 360}{303} \approx 118$ revolutions as in Table 11.

The cycle time for a spindle speed $n_s = 3{,}500$ rpm will be:

$$T_c = \frac{60 n_{cycle}}{n_s} = \frac{60 \times 118}{3{,}500} = 2.02 \text{ sec.}$$

The gross rate of production will be

$$Q_g = \frac{60}{T_c} = 29.7 \text{ pcs per min.}$$

The actual or net rate of production with a utilisation factor $\eta = 0.95$ will be

$$Q_a + Q_g \eta = 29.7 \times 0.95 = 28 \text{ pcs per min.}$$

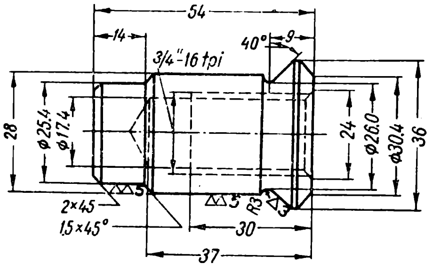
§ 62. TOOLING LAYOUT AND OPERATION SHEET FOR MULTIPLE-SPINDLE AUTOMATIC BAR AND CHUCKING MACHINES

The order to be followed in designing the setup for a multiple-spindle automatic may be illustrated by the production of a special nut on a four-spindle automatic bar machine, model 123 (Table 12).

Table 12

Tooling Layout and Operation Sheet for the 4-Spindle Automatic Bar Machine, Model 123

Workpiece



Spindle

Change gears		n_s, rpm	332
A=52	B=52		

Camshaft

Change gears		Small worm	Gearing ratio	n_{cs}, rpm
C D	40 44	Single-thd.	0.00160	18.2

High-speed drilling attachment	Auxiliary independent-feed spindles			
	Lever arm ratios			
Relative speed, rpm	1st position	2nd position	3rd position	4th position
			1:1.7	

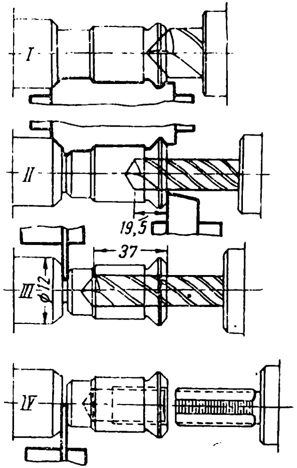
Threading attachment spindle

Part name	Material	Stock	Advancing			Backing out		
			Change gears		Relative speed, n 95 rpm	Change gears		Relative speed, n 172 rpm
Nut	Steel 10	36 mm round bar	H I	25 53		K L	39 39	

Position	Travel	Operation element	Machined length, mm	Actual travel, mm	Cam rise, mm	Angle of camshaft rotation	v, mm/min	s, mm/rev.	Notes
I	Longitudinal	Spot drill to diam 22 mm . .	11	20	20	117°	—	0.099	
	Cross	Rough form	5	7	7	119°	37.6	0.034	

(*Continued*)

II	Longitudinal	Drill 17.4 mm and face end	17	20	20	117°	—	0.099	—
	Cross	Finish form	2.83	4	4	117.5°	—	0.02	—
III	Longitudinal	Drill 17.4 mm to depth 37 mm	18	20	20	115.5°	—	0.099	—
	Cross	Cut-off, first step to diam 12 mm	4.2	6	6	118.5°	—	0.03	—
IV	Longitudinal	Tap thread	30	—	—	68.8°	5.7	—	44.3+21.5
	Cross	Cut-off	6	9	9	120°	—	0.043	



Accepted angle of camshaft rotation for working movements	120°	Rate of production	
Angle of camshaft rotation for engaging high-speed rotation	4.5°	Gross production, Q'_g	pcs/hr—87
Total angle for working movements	124.5°		pcs/shift —696
Angle of camshaft rotation for idle movements	235.5°		
Time for working movements, sec	39.1	Actual production (18% losses) Q'_a	pcs/hr —71
Time for idle movements, sec	2.2		
Total machining time, sec . .	41.3		pcs/shift —568
Seconds to make one piece . .	41.3		

Model 123 is a multiple-position machine tool in which the workpiece is machined progressively in all of the positions.

A feature of such machines is the possibility of distributing the machining operations between the positions so that the time required in each position will be as small as possible and equal to that of the other positions.

The main problem, therefore, is to properly lay out the sequence of operations so as to obtain a maximum rate of production of work which complies with the accuracy specifications.

Operation elements requiring much time are sometimes divided between two or even three positions. This divides the time, which would limit the production capacity at any one position, between several positions.

It is advisable to arrange finishing operations, when designing the tooling layout, in separate positions. In this way more accurate work may be produced. Since a setup on a multiple-spindle automatic includes a considerable number of tools, it is important to use the simplest possible tools and standard types wherever feasible. The application of complex tools, requiring time-consuming setting-up and adjustment, will reduce the efficiency of these automatics. The methods used in machining the nut of Table 12 illustrate process planning on multiple-spindle machines.

The part is to be made of bar stock, steel 10, 36 mm in diameter. A hole is to be drilled and tapped and the external surface is to be turned to a complex form. In addition, the finished part is to be cut off. These machining operations are to be performed in the four positions of the model 123 automatic, which has four side toolslides, a two-position end toolslide, and two end-working tool spindles.

The part drawing specifies a surface finish of $\nabla 5$ for all external surfaces. This required accuracy, in conjunction with the larger diameter at the front end of the part, stipulates the use of side toolslides to turn the outer surfaces. Thus, the 1st and 2nd positions may be used for rough forming and finish forming these surfaces. The 3rd and 4th positions are used for cutting off in two steps.

Before drilling the hole, it is necessary to spot drill. For most efficient practice, the spot drill should also machine the chamfer in the hole. The hole could be drilled in a single position, but in this case, this operation would be twice as long as the other operations. This limiting machining operation is, therefore, divided between the 2nd and 3rd positions. The thread is cut in the 4th position.

In addition to machining, provision must be made in the 4th position for stock feeding and chucking. Therefore, the sum of the machining time in the 4th position and the time required for stock feeding and chucking should not exceed the time required for processing at each of the other positions.

After laying out the sequence of operations, it will be necessary to select the cutting tools and the holders for form tools, drills, reamers, taps, etc. It is advisable to use the standard holders, furnished with the machine, for this purpose. As far as cutting tools are concerned, it will be necessary to decide which should be made of high-speed steel and which should be tipped with cemented carbides for most efficient operation. On the basis of these data, the operation sheet may be drawn up and filled in.

Columns 1, 2, and 3 are filled in in accordance with the accepted sequence of operations and tooling layout, while the machined length in column 4 is based on the dimensions of the workpiece. These machined lengths are increased by 2 or 3 mm to obtain the actual travel of the slides (column 5) and the cam rise (column 6).

The cutting speed is selected to suit the most severe operation (as concerns stock to be removed, rate of feed, work diameter and type of tool) and the corresponding spindle speed is calculated. Since all the spindles of such multiple-spindle automatics rotate at the same speed, the cutting speeds may easily be calculated for each position. In our example, the limiting operation will be rough forming in the 1st position. This operation may be performed at a cutting speed of $v = 38$ to 40 m per min with high-speed steel tools (this value could be considerably increased if high speed machining was employed). The corresponding spindle speed will be:

$$n_s = \frac{v \times 1{,}000}{\pi d} = \frac{38 \times 1{,}000}{3.14 \times 36} = 337 \text{ rpm.}$$

The nearest lower speed is selected of those actually available on the automatic and listed in its service manual. This will be:

$$n_s = 332 \text{ rpm.}$$

The corresponding cutting speed will be $v = 37.6$ m per min (column 8).

The main drive change gears required to provide the above spindle speed are also given in the service manual. They are:

$$A = 52 \text{ teeth and } B = 52 \text{ teeth.}$$

These data are to be set down in the operation sheet, under the heading "Spindle".

Thread cutting in the 4th position is performed at a much lower speed. In the example $v_{thd} = 5.7$ m per min (column 8) and, therefore, the relative speed in thread cutting should be:

$$n_r = \frac{5.7 \times 1{,}000}{19 \times 3.14} \approx 95 \text{ rpm.}$$

This means that the thread cutting spindle must rotate so that the difference between its speed and that of the work spindle is 95 rpm. The service manual lists the change gears

$$H = 25 \text{ teeth and } I = 53 \text{ teeth}$$

to provide the above-required relative speed of the thread cutting spindle.

A higher relative speed is used to back the tap out of the threaded hole. The value $n_r^b=172$ rpm may be taken for this purpose; it corresponds to the change gears:

$$K=39 \text{ teeth and } L=39 \text{ teeth.}$$

These data are set down under the heading "Threading attachment spindle".

The rates of feed s are selected from handbook data to suit the given processing conditions. Each side toolslide may have its own feed, independent of the other toolslides but all the end-working tools, mounted on the same end toolslide (accommodating the 1st, 2nd and 3rd positions in the given example), have the same feed. Only the end-working threading attachment spindle in the fourth position has independent feed facilities.

The selected feeds are set down in column 9.

The next step is the calculation of the cycle time. The necessary data for the model 123 automatic are as follows:

1. Approximately 120° of camshaft rotation is occupied by the working (low-speed) motion.
2. An additional angle of 4.5° at low speed is required for engaging the high-speed clutch.
3. The angle of rotation at high speed for spindle carrier indexing, locking, rapid toolslide approach and withdrawal and other idle motions is 235.5°.

This will sum up to 360° or one full revolution of the camshaft.

The idle time t_i required for high-speed camshaft rotation through 235.5° is a constant value and in no way depends on the machining time. This idle time is indicated in the service manual.

The cycle time T_c for these machines is calculated from the formula

$$T_c=t_w+t_i \tag{44}$$

in which t_w is the working or machining time in the cycle in sec;
t_i is the idle time in sec.

Automatic, model 123, has an idle time $t_i=2.2$ sec.

The machining time is calculated from the data of columns 4 and 9 (Table 12) and the selected spindle speed—332 rpm in this example.

Slow-speed camshaft rotation occupying 120° is usually employed only for cutting off (4th position). The operation of other tools is accommodated in 117° or 118° of camshaft rotation.

The travel of the tools mounted on the end toolslide in this example will be $l=20$ mm at a feed of $s=0.099$ mm per revolution. The number of spindle revolutions required for these operations will be

$$n_o=\frac{l}{s}=\frac{20}{0.099}\approx 202 \text{ revolutions.}$$

Therefore, the time t_o required for the camshaft to rotate through the angle indicated in column 7 will be

$$t_o = \frac{n_o \times 60}{n_s} = \frac{202 \times 60}{332} = 36.5 \text{ sec.}$$

If, then, the camshaft is to rotate through 117° in 36.5 sec, the time t_w required to complete the whole slow-speed rotation of 124.5° will be

$$t_w = \frac{36.5 \times 124.5}{117} \approx 39.1 \text{ sec.}$$

Change gears C and D for the camshaft drive are selected from the speed and feed tables in the service manual for a machining time of 39.1 sec at a spindle speed of $n_s = 332$ rpm ($C = 40$ teeth and $D = 44$ teeth).

The cycle time is the sum of the machining and idle times:

$$T_c = t_w + t_i = 39.1 + 2.2 = 41.3 \text{ sec.}$$

The gross rate of production will then be:

$$Q'_g = \frac{60 \times 60}{T_c} = \frac{3{,}600}{41.3} = 87 \text{ pcs per hr.}$$

Since there will be an inevitable time loss for adjustments, repairs and tool changes in operation, the actual production Q'_a will, of course, be less than the gross value Q'_g. A time loss of 18 per cent will be suitable for the given example. Then the actual rate of production:

$$Q'_a = \frac{87\,(100 - 18)}{100} \approx 71 \text{ pcs per hr.}$$

This calculation completes the operation sheet which is used to set up the automatic.

§ 63. DESIGNING CYLINDER CAMS

Cylinder cams are designed on the basis of the same data as for plate cams but by a somewhat different method. If a cylinder is developed on a flat surface, a rectangle is obtained (Fig. 91). The height of this rectangle equals the height of the cylinder while the width equals the circumference or developed length. The developed length is:

$$L = \pi D \text{ mm} \tag{45}$$

in which D is the diameter of the cylinder in mm.

In the design of cylinder cams, the developed length ($L = \pi D$) is divided into 360 equal parts, each corresponding to 1° of cam drum rotation.

Cylinder cams, as well as the plate types, must have sections for rapid approach, working feed, and rapid withdrawal or return. Each of these sections is a helical surface but with different helix angles. On the development of a cylinder cam, a helix will be a straight line. All the calculations required for laying out a cylinder cam may be made on the basis of the tool travel l, feed s in mm per spindle revolution and the number of spindle revolutions n_0 for each operation element. These values are determined in the same manner as for plate cams.

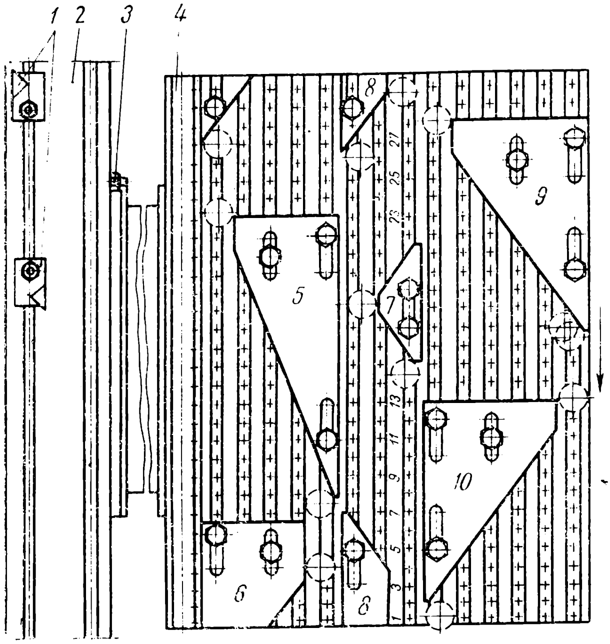


Fig. 91. Development of cylindrical drums and cams for the semi-automatic lathe, model 116.

1 — high- and low-speed cams, *2* — clutch-operating drum, *3* — follower, *4* — large cam drum, *5* and *6* — front slide cams, *7* and *8* — wedge bar cams, *9* and *10* — rear slide cams.

The rise h of the curve on the working section of the cam (under the assumption that there is a 1 to 1 ratio in the lever system, i. e., equal lever arms) will equal the tool travel:

$$h = l \text{ and } n_0 = \frac{l}{s} = \frac{h}{s}. \tag{46}$$

If, however, the ratio of the lever system from the cam to the slide equals m, then:

$$h = \frac{l}{m} \text{ mm.} \tag{47}$$

The relation of the working feed s to the cam rise is expressed by the formulas:

$$s=\frac{h\times m}{n_o}i \text{ mm per revolution} \qquad (48)$$

or

$$s=\frac{h\times 360}{\beta_o}im \text{ mm per revolution} \qquad (48')$$

in which β_o is the angle of camshaft rotation in degrees for the given operation;

i is the gearing ratio from the spindle to the camshaft:

$$i=\frac{n_{cs}}{n_s}$$

in which n_{cs} is the working (slow) speed of the camshaft in rpm;

n_s is the spindle speed in rpm.

The time required for machining when cylinder cams are used is determined in the same way as for plate cams.

§ 64. TOOLING LAYOUT AND OPERATION SHEET FOR A HYDRAULIC SEMI-AUTOMATIC LATHE

All movements of operative units in hydraulic lathes are actuated, as a rule, by hydraulic cylinders and pistons. Their speed of travel depends upon the amount of oil delivered to the piston end of the cylinder per minute as well as the area of the cylinder bore (see formulas 27 and 28).

The rate of slide feed, therefore, is expressed in mm per min and not in mm per spindle revolution. Obviously, the handbook value for the rate of feed, given in mm per revolution, must be converted, in feed selection, into mm per min (s_{min}) by using the formula

$$s_{min}=s\times n_s \text{ mm per min.} \qquad (49)$$

The time for each operation element is determined, from the working travel l, by the formula

$$t_o=\frac{l}{s_{min}} \text{ min} \qquad (50)$$

or

$$t_o'=\frac{60\times l}{s_{min}} \text{ sec.} \qquad (50')$$

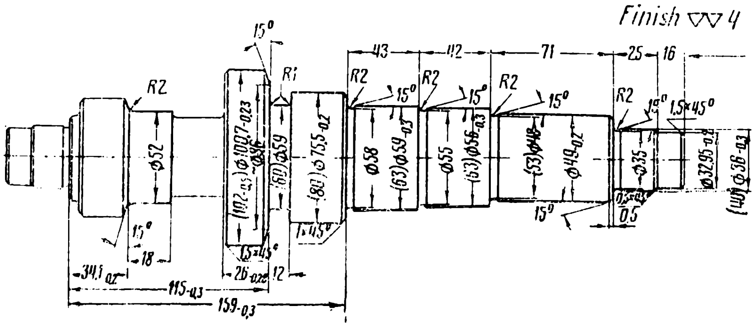
which do not essentially differ from formulas (34) and (34').

Rapid slide approach and withdrawal movements do not depend on the spindle speed in these lathes and are calculated on the basis of machine data in the service manual. It must be noted that

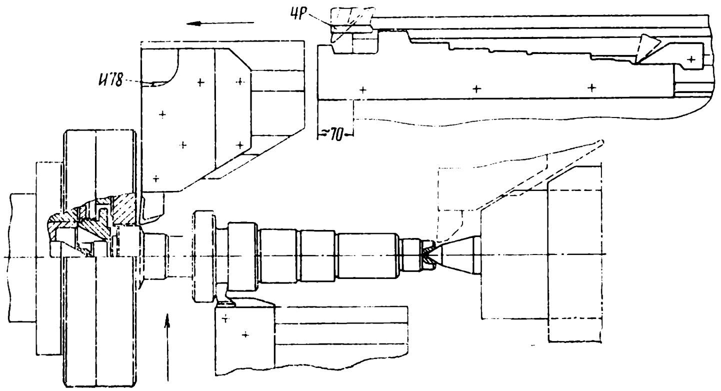
Table 13

Tooling Layout and Operation Sheet for the Hydraulic Semi-Automatic Tracer-Controlled Lathe, Model 1722

Hydraulic semi-automatic tracer-controlled lathe, model 1722		Material and blank — forging of steel 18ХГТ			
Maximum cutting speed, m/min	Spindle speed, rpm	Speed gearbox			
		Double cluster gear position		Change gears	
		R. H.	L. H.	A	B
143.5/42.3	448	I	II	23 T.	56 T.



Sketch of workpiece



Tooling layout

Total cycle time, minutes		2.16	Machining time, minutes					1.86
Slide	Operation element	Travel, mm	Feed, mm/min	Feed, mm/rev	Spindle revolutions required	Consecutive spindle revolutions		Machining time, minutes
						start	finish	
Tracer-controlled	Turning contour to template	375	201.6	0.45	833	0	833	1.86
Facing	Cutting 12 mm groove	15	89.6	0.2	(75)	(768)	(833)	(0.17)

Idle time $=0.3$ min

$\Sigma o=833;\ t_{\mathrm{w}}=\frac{833}{448}\approx 1.86$ min.

the approach and withdrawal speeds often differ and are always expressed in metres per minute (m/min). Slide travel is usually expressed in millimetres and it will be necessary to express the slide speed in mm (1 m per min=1,000 mm per min).

The rapid approach time (t_{ra}) is determined from the formula:

$$t_{ra}=\frac{l_{ra}}{1{,}000v_{ra}}\text{ min} \tag{51}$$

or

$$t'_{ra}=\frac{60\times l_{ra}}{1{,}000v_{ra}}\text{ sec.} \tag{51'}$$

The rapid withdrawal time (t_{rw}) is determined from similar formulas:

$$t_{rw}=\frac{l_{rw}}{1{,}000v_{rw}}\text{ min} \tag{52}$$

or

$$t'_{rw}=\frac{60\times l_{rw}}{1{,}000v_{rw}}\text{ sec} \tag{52'}$$

in which l_{ra} and l_{rw} are the lengths of rapid approach and withdrawal travel of the slide in mm;

v_{ra} and v_{rw} are the speeds of rapid approach and withdrawal in m per min.

Example: The total travel of a slide is 350 mm. Of this, 200 mm is occupied by working feed at $s_{min}=100$ mm per min. The rapid approach speed is $v_{ra}=2$ m per min and the rapid withdrawal speed is $v_{rw}=1{,}5$ m per min. Determine the rapid approach time (t'_{ra}), machining time (t_o), and the rapid withdrawal time (t_{rw}).

$$l_{ra}=350-200=150\text{ mm;}$$

$$t'_{ra}=\frac{60\times 150}{1{,}000\times 2}=4.5\text{ sec;}$$

$$t'_o=\frac{60\times 200}{100}=120\text{ sec;}$$

$$t'_{rw}=\frac{60\times 350}{1{,}000\times 1.5}=14\text{ sec.}$$

The summary time required for all side movements will be

$$t'_{ra}+t'_o+t'_{rw}=4.5+120+14=138.5\text{ sec.}$$

In regular practice it is necessary to increase the working feed travel slightly and to correspondingly reduce the length of rapid approach. This will prevent the tool from starting the cut at the rapid approach speed.

The tooling layout and operation sheet for turning a stepped shaft on a hydraulic semi-automatic tracer-controlled lathe, model 1722, (Table 13) are to be designed with the same procedure used for automatic lathes having a camshaft (Tables 10, 11, and 12).

§ 65. DESIGN AND MANUFACTURE OF TOOLING

All elements required in a machine tool setup are called the *tooling*. They include cams, cutting tools, fixtures, and holders. Preference should always be given to standard tooling if it can be used in the setup.

Before designing special tooling, it is advisable to check whether cams and cutting tools for similar workpieces were manufactured previously and whether they are available and suitable for the present setup. Thus only non-available camming, and special cutting tools and fixtures need be designed and made.

The most time-consuming work in tooling is cam manufacture. Plate cams are made of stock blanks of steel 20X, steel 15, or of pearlitic phosphoretic cast iron. The following sequence of operations is usual practice: 1) turning on a lathe and boring the central hole, 2) drilling and reaming the locating pin hole, dividing the cam surface into hundredths or other divisions, and laying out the outline of all lobes on the cam, 3) milling the outline on a milling or special machine, 4) filing the outline, 5) heat treatment and 6) grinding the central hole.

Cylinder cams are made of steel 45, steel 40X or cast iron grades CЧ 24-44 and CЧ 28-48. They may be designed as drums in which slots of the required form are milled or as removable cam plates which fit on and are held by screws to the cylindrical surface of the cam drum. Hollow cylinders, machined inside and outside, are usually used as blanks for the above cams which are simply cut out of the blanks. Holes are drilled and counterbored in the cut-out blanks for screws and then the blanks are secured on a drum and the outlines are milled. If cylinder cams are made of steel, they are heat treated. after checking the rise and outline.

§ 66. SETTING UP AUTOMATICS AND SEMI-AUTOMATICS

Before attempting to set up an automatic or semi-automatic lathe, one must be well acquainted with the date and setting-up instructions given in the service manual. The setup must comply, in every respect, with the tooling layout and operation sheet.

Setting up consists in the following:

a) installing and adjusting the stock feeding and chucking devices;
b) setting the required work spindle speed;
c) setting the camshaft speed to the required cycle time;
d) installing cams or stops;
e) installing cutting tools, holders, and fixtures on the slides;
f) setting the travel of the operative units; adjusting tools and stops;
g) checking the operation of all operative units and all protective devices;

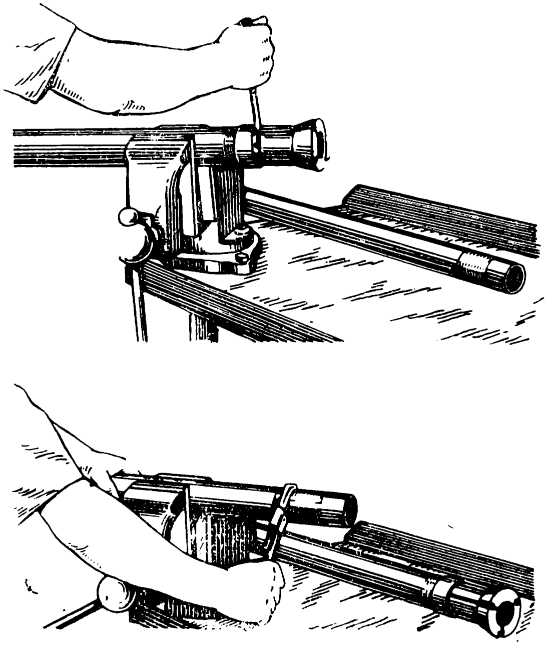


Fig. 92. Changing collets and stock pushers for multiple-spindle bar machines.

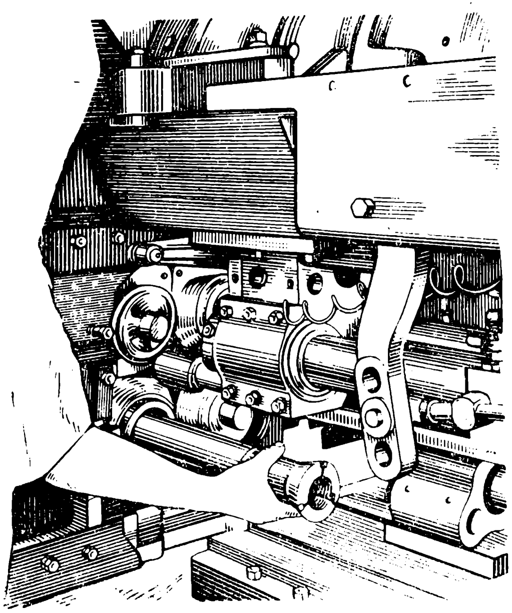


Fig. 93. Installing a collet tube with a collet on a 4-spindle automatic, model 123.

h) test run and first-piece inspection;

i) final adjustments to obtain exact work size.

Installing and adjusting stock feeding and chucking devices on bar machines consists in inserting a collet tube with a collet of the required size and shape and in adjusting the clamping force. The latter is varied by adjusting the chucking sleeve. Then a stock pusher (or feeding finger) of the required size is screwed on the feeding tube. The stock stop may be adjusted at the same time.

To change the collet and stock pusher, the tubes must be removed from the work spindle (Fig. 92). Collets and stock pushers are then carefully unscrewed (Fig. 93).

Next, the stock feeding mechanism is adjusted as required. As a rule, stock feed is adjusted to a value 5 or 6 mm longer than the length of the workpiece. In multiple-spindle automatic bar machines, the stock feeding and chucking mechanisms are to be adjusted in each work spindle. Magazine automatics require adjustment of the chucking device and, in addition, of all mechanisms which feed the blank from the device to the spindle and the rod which pushes the blank into the chuck.

Chucking devices of semi-automatics require adjustment to the diameter of the workpiece. Provision must be made for a diameter slightly larger than the nominal value.

The required work spindle and camshaft speeds are set by installing the change gears, indicated in the operation sheet, into the main drive and camshaft drive gear trains. In models in which the camshaft has two speeds of rotation (a high constant speed for idle movements and a set-up slow speed for working feeds), the adjustment of the high-speed clutch must be carefully checked.

At this stage, the cams may be mounted on the camshaft.

Plate cams have a locating pin hole on the radius of the 0 hundredth which coordinates several cams in relation to each other. Cam lobes are milled on a special fixture in which they are located from this hole.

Cylinder cams are usually designed as separate cam plates fastened by screws on a drum which is mounted on the camshaft.

Cam drums have a sufficiently large number of threaded holes on the outside surface, numbered along the circumference of the drum. Cam plates are mounted on the drums in accordance with the tooling layout and operation sheet. The gearing diagram of the model МП5 semi-automatic chucking lathe, controlled by cylinder cams, is shown in Fig. 94.

When the automatic has been set up, it is advisable to start it for an idle test run for 5 or 10 minutes to check its operation.

Setting up an automatic lathe takes considerable time, during which the machine is idle. Systems of automaticity based on constant cams or hydraulic drives are being applied more and more widely in the latest designs to reduce the time lost in setting-up operations. Several Soviet machine tool plants have developed automatic lathes which can be set up in from 30 to 90 minutes in place of the 120 to 240 minutes required in previous models.

Many Soviet setup men have substantially reduced the setting-up time for automatics and semi-automatics by doing certain preparatory work before stopping the machine.

If definite work has not been assigned to each machine in quantity and date schedules, it will be necessary for the setup man to distribute the work, on the basis of the weekly or monthly production programme, in such manner that change-overs from one

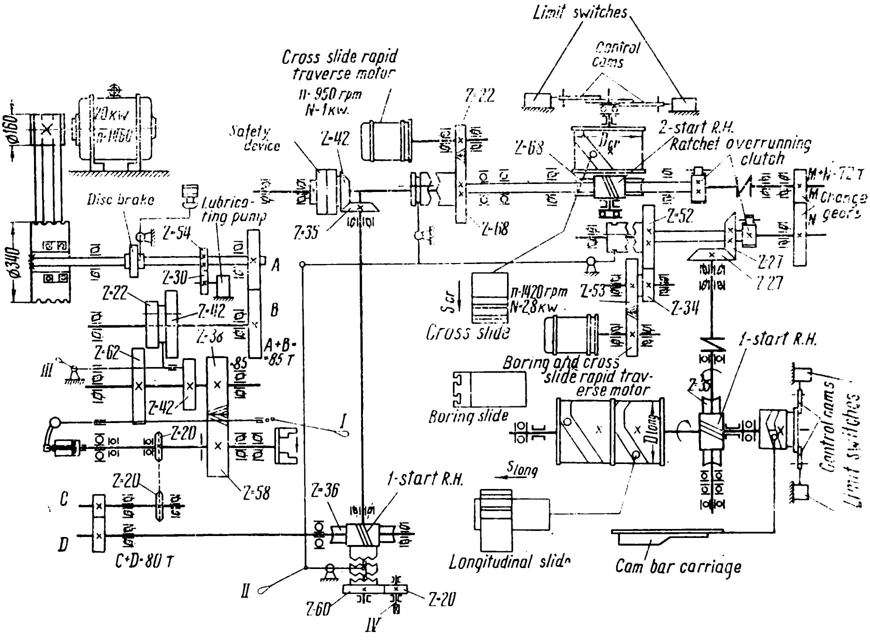


Fig. 94. Gearing diagram of the single-spindle semi-automatic lathe, model MP5, with units controlled by cylinder cams.

$$n_s = 1,460\,\frac{160}{340}\times\frac{A}{B}\times\frac{22}{62}\times\frac{38}{58}\ \text{rpm};$$

$$n'_s = 1,460\,\frac{160}{340}\times\frac{A}{B}\times\frac{42}{42}\times\frac{38}{58}\ \text{rpm}$$

$$s_{long} = 1_{sp.\ rev}\,\frac{20}{20}\times\frac{C}{D}\times\frac{1}{36}\times\frac{35}{42}\times\frac{M}{N}\times\frac{27}{27}\times\frac{1}{35}\ \pi D_{long}\tan\beta_{long}\ \text{mm/rev};$$

$$s_{cr} = 1_{sp.\ rev}\,\frac{20}{20}\times\frac{C}{D}\times\frac{1}{36}\times\frac{35}{42}\times\frac{2}{68}\ \pi D_{cr}\tan\beta_{cr}\ \text{mm/rev};$$

$$s_{l\ rt} = 1.42\,\frac{17}{53}\times\frac{34}{52}\times\frac{27}{27}\times\frac{1}{35}\ \pi D_{long}\tan\beta_{lrt}\ \text{m/min};$$

$$s_{c\ rt} = 0.95\,\frac{22}{68}\times\frac{2}{68}\ \pi D_{cr}\tan\beta_{c\ rt}\ \text{m/min}.$$

workpiece to another involve a minimum time loss. For this purpose:

1. The various work should be sorted into groups having like sequences of processing operations. These groups are then allotted to different automatics so that minimum replacements of cams, fixtures, holders, etc., are required to change over from one workpiece to another.

2. Collect all drawings, operation sheets, fixtures and cutting tools that will be required for a new setup before stopping the automatic lathe.

3. Try to time change-overs so that they need not be performed during working time (during lunch time or after the shift).

4. Make fine adjustments of the cutting tools, wherever possible, to gauges and measuring tools and not by turning trial pieces.

§ 67. SETTING UP THE TRAVEL OF UNITS CARRYING CUTTING TOOLS

Toolslides, turret, and auxiliary tool spindles are first set up approximately and then fine adjustments are made. It is advisable to carry out these coarse settings of units and tools to a master sample or template. The master sample is clamped in the chuck or in the collet (if the part is made of bar stock). It is located axially by the cut-off tool and the stock stop.

After setting up the master sample, the camshaft is rotated slowly by hand through the full cycle of the machine. This will check the movements of all the slides with the mounted tools and enable their positions to be adjusted in reference to the master sample. Stops should be adjusted, at the same time, to the end positions of all slides controlled in this manner.

This work is called process setting-up and is performed differently for automatics and semi-automatics of different design. Process setting-up methods also depend on the design of the tool holders and tool clamping devices.

The construction and sharpening of cutting tools require especial attention in the performance of various operations. The following notes are of importance in setting up:

a) *Automatic bar machines*:

1) The bar stock feed stop is to be set so that the stock feed is equal to the work length plus the width of the cut-off tool.

2) To turn parts of exact length, especially on multiple-spindle automatics, the front end of the workpiece must be faced in the operation.

3) The main requirement in machining accurate holes is proper alignment of the drill and work axes; this may be achieved by spotting or centring. No spotting is required for shallow holes.

4) Thread cutting should not be overlapped, if possible, with other operations and should be performed before cutting off has proceeded to any appreciable extent (while the work is still rigidly supported by the stock).

5) Thread cutting with a tap or die is performed with the same direction of rotation of the cutting tool and the work (or with a stationary tool). The cutting speed will be the difference in the speeds of the work and tool.

6) Right-hand thread will be obtained if the tool leads the work (cutter rotates faster than the work); left-hand thread is cut if the tool lags behind the work. (This is true for clockwise rotation when looking at the spindle nose.)

7) In thread cutting, the length of power longitudinal feed does not exceed one thread lead to start the die or tap which then runs on or screws into the work to provide for further feed movement.

8) If thread is cut with a self-opening die, there is no need to run the latter off the thread but the operating cycle should provide time for opening the die.

9) External thread is usually rolled only in comparatively soft materials or if it is located beyond a shoulder.

10) The cutting speed for core-drilling and reaming must be reduced in comparison with turning, drilling, and boring.

11) Knurling may be done from either the cross or end-working toolslides but, in either case, the work must be supported by a roll on the opposite side.

12) In cross drilling, milling flats and other similar operations, the spindle with the work is stopped by a braking device.

13) If separate blanks are used on bar machines, a magazine loading device must be installed and the stock feeding mechanism is employed as a stop and to eject the finished workpiece.

b) *Semi-automatic centre-type and chucking machines*:

1) External surfaces of long workpieces are turned with the work held between centres. If the length exceeds 10 or 15 diameters, steadyrests must be used.

2) Comparatively short work of large diameter is held in a chuck.

3) External surfaces may be turned with multiple-tool, single-tool, or combined setups. Multiple-tool and combined setups provide for the highest rates of production. Setup time is less for single-tool arrangements. The combination method comprises single-tool tracer-controlled machining in the longitudinal direction, in conjunction with a multiple-tool arrangement for facing shoulders and cutting grooves, and is highly effective in many cases.

4) Separate blanks are usually turned in two settings. First one side is machined and then the other side, in a new setup. The machining should be divided so that a reliable and accurate locating surface is provided for the second setup.

5) Holes should be machined, whenever possible, simultaneously with the external surfaces.

6) Separate blanks may be efficiently clamped in pneumatic or hydraulic chucks.

After setting up the machine, it is started and run through from one to three cycles. All of the safety devices are checked during this run and the finished parts are inspected. On the basis of this inspection, final adjustments are made on all operative units and their positions in reference to the work, all positive stops are adjusted and locked firmly and all tripping devices are likewise finally adjusted.

The accuracy of a setup should be checked from time to time. This is done. without stopping the machine, by sampling inspection of the finished pieces.

If inspection of the dimensions or surface finish of the workpiece indicate that its quality is near to the permitted limits, the machine is stopped and further adjustments are made.

All safety rules must be strictly observed in setting up automatics and semi-automatics. All protective devices must be properly installed before starting the machine.

All handles and levers, designed as removable and used only in setting up. should be removed before starting up. Workpieces should never be checked or measured without fully stopping the machine. The movements of the setup man should not be hampered in any way during setting up operations. He must arrange his tools so that they are always conveniently at hand.

§ 68. SPECIAL FEATURES IN SETTING UP HYDRAULIC LATHES

Hydraulic drives provide for rapid change-overs in the setups of machine tools. The less time lost in changing over from one workpiece to another, the more efficiently such automatic lathes can be used for small lots.

A hydraulic drive is self-controlled or it is controlled from electric devices but it does not require complex expensive cams, designed specially for each new cycle.

After filling the tank with oil, the pump drive motor is switched on and all units are rapidly traversed, by manual controls, from one end of their travel to the other. This is repeated several times until all air, trapped in the cylinders and pipelines, is driven out. *Smooth slide movement indicates that the system is free of air.* Then the hydraulic control units of the clamping devices and slide travel are tested and adjusted.

Before setting up a hydraulic automatic or semi-automatic, it is necessary to test the working fluid in the hydraulic system which must be feasibly pure and should contain no air. Air in the oil will cause foam on the surface. Dirt in the oil leads to fluctuations in the pressure and flow in the system and, as a consequence, to abnormal operation. After filling the tank with fresh oil (or after replenishing), the filters should be cleaned daily for several days. Reliable hydraulic system operation may be ensured if the grades of oil "Spindle 3", "Industrial 30", and "Turbine L" are used. Lack of oil in the system will cause rapid heating. This reduces oil viscosity and increases leakage.

All hydraulic lathes operate on a setting-up and an automatic cycle. Either cycle is selected by a rotary switch.

It is highly desirable to employ master samples for setting up these lathes.

The following order of setting-up operations has proved efficient for hydraulic lathes: 1) Regulate all control devices of the work clamping facility (the latter is usually in the "Unclamp" position after removing the work), 2) tool block and other holders for cutting tools are mounted, 3) lengths of working travel are first adjusted coarsely with hand controls; final adjustments are made by setting stops and dogs which actuate the corresponding control elements to obtain preset movements, 4) the coordination or interaction of the kinematic, hydraulic, and electric systems are checked, 5) the cycle is run through several times from manual controls as a test, 6) the automatic cycle is switched on, 7) the actual dimensions of the finished work are checked, 8) final adjustments are made on all stops and dogs, and 9) the machine is started for regular automatic operation.

The following must be taken into consideration in setting up hydraulic lathes:

1. Check valves (type Γ51) will operate properly only if the valve member seats tightly.

2. Relief valves with overflow devices (type Γ52) and pressure valves (type Γ54) are designed to maintain a definite pressure and also to protect the system against overloads. In their adjustment, see that the oil can drain to the tank only through the valve and that they are clean of foreign matter.

3. Reducing valves with pressure adjustment devices (type Γ57) are designed for pressure reduction in a hydraulic system to obtain a constant pressure (in an auxiliary line), reduced in comparison with the pressure developed by the pump (in the main line). Clockwise rotation of the adjustment screw will increase the pressure after the valve.

4. Throttle valves with flow control (type Γ77) and throttle valves (type Γ55) are designed to regulate the travel speed of hydraulic units by changing the cross-section of the slit in the throttle valve through which the oil passes. Clockwise rotation of the dial should increase oil flow (otherwise the movement of the valve member in the body must be checked, as well as the operation of the spring). If oil flow through the throttle valve stops, clean the slit by turning the dial to each side several times.

§ 69. TOOL RESETTING

Resetting in automatics and semi-automatics comprises the replacement of dull tools and adjustment of the new (sharpened) tools.

Resetting frequency depends chiefly on tool life. *The longer the cutting tools operate without dulling, the less frequently they require resetting.*

On the other hand, tool life decreases with an increase in the cutting speed.

Cutting speeds and feeds are usually selected in accordance with the economic tool life T_{ec} which is calculated for machining steel by the formula:

$$T_{ec}=k(m-1)t_{re}\ \text{min} \tag{53}$$

in which k is the number of tools in the setup;

m equals 5 for high-speed steel tools and 4 for carbide tipped tools;

t_{re} is the time in min required to reset (adjust) one tool

For resetting, the machine should be stopped in that part of the cycle where all of the operative units (slides, etc.) are withdrawn to their initial positions and the tools are retracted from the work.

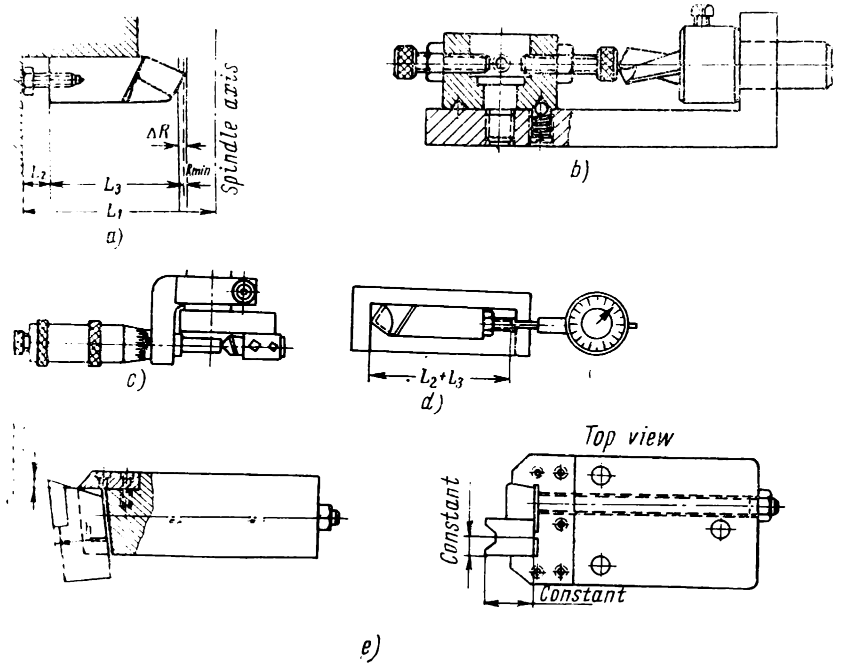


Fig. 95. Fixtures for preset tooling.

a, *c*, *d*, and *e*—for single-point tools, *b*—for centre tools.

Failure to observe this condition may lead to tool breakage and to rejection of the workpiece being machined.

In complete resetting of multiple-spindle automatics or semi-automatics, it is necessary to finish the machining operations in all of the spindles before stopping the machine. In stopping the machine, observe the following order: first disengage camshaft rotation and then switch off the main drive.

Resetting, in many Soviet plants, is done in accordance with a planned schedule (scheduled resetting), i. e., when a definite period of time has elapsed. It is desirable to do all resetting at lunch time or after work when the machines stand idle. Scheduled resetting reduces time losses; it increases the utilisation of machines and their rate of production.

Special interchangeable tool holding devices, which can be quickly replaced and in which the tools are accurately preset from master gauges, will reduce idle time of the machine during resetting. In this case the entire holder with the preset tools replaces an identical holder. Such an arrangement is known as *preset tooling* and it sharply reduces resetting time.

Fixtures for accurately setting single-point and centre tools (drills, counterbores, core-drills, etc.) are illustrated in Fig. 95. After adjusting the position of the tool in the holder, the latter can be installed on the machine without further adjustment to the work size.

CHAPTER III

SPOILAGE — TYPES, CAUSES, AND PREVENTION

§ 70. TYPES OF SPOILAGE

Spoilage may be prevented only when each operator knows what causes the various types of spoilage and is able to quickly eliminate them.

In general, spoilage may be classified as follows: 1) spoilage due to poor-quality blanks or stock, 2) spoilage in setting up, and 3) spoilage during operation.

Spoilage due to the quality of the blank obliges the material to be inspected to discover fissures, laps, haircracks and other external defects.

Heavily distorted bar stock, as well as bars on which scale and burrs at the ends have not been removed, should never be used in automatics as they will cause premature wear and breakdowns. Each case of defective stock or blanks should be reported to the foreman.

Spoilage in setting up is due to the necessity of making one or several trial workpieces before the cutting tools have been finally adjusted to the size of the work.

Spoilage in setting up may be reduced by various measures, among the first of which, are the use of master samples and preset tooling (see § 69). A master sample should have an extension for clamping in the collet or chuck.

When the most accurate operations on multiple-spindle automatics and semi-automatics are not performed in the last positions, a considerable amount of spoilage may result in setting up, since errors will be discovered only in the last position and all the blanks in the preceding positions will be spoilage. In the latest Soviet models, provision has been made for removing and measuring the work in any position. This enables the amount of spoilage of this type to be sharply reduced.

Spoilage during operation may be the result of: (a) *the machine being out of order*, (b) *defects in the setup*, (c) *cutting tools being in bad condition, and* (d) *measuring tools being in an unsatisfactory condition.*

Defects in the operation of the machine are one of the principal reasons for spoilage. Therefore, when rejects appear, the first thing to do is to check work spindle rotation, clearance in the spindle bearings and in the slide ways, locking of the spindle carrier and other units that might affect the accuracy of dimensions or geometrical form of the rejected work. Upon the completion of these measures, automatics should be subjected to an accuracy test (see § 137).

A defective setup may cause spoilage because the cutting tools are set to the upper (for shafts) or lower (for holes) limits. In this case, even after the slightest wear which appears after machining a small number of parts, the cutting tools will produce work of a size not within the tolerance limits. This can be illustrated by an example: a shaft is to be turned to the diameter $20_{-0.1}$ mm (i. e., with a tolerance of 0.10 mm); properly sized parts will have diameters from 19.90 mm to 20 mm. If the cutting tool is set for the dimension 19.90, it will produce work of the proper size until its cutting edge has a wear of 0.05 mm ($19.90+2\times0.05=20$ mm). If, on the other hand, the tool is set to the size 20 mm, it will produce rejects after the slightest wear, for example, 0.005 mm ($20+2\times0.005=20.01$ mm).

The following rule is useful in this connection: *in setting up, set tools machining external surfaces near to the lower tolerance limit and tools machining holes, to the upper limits.*

Spoilage may also be a result of low-quality tools or poorly sharpened tools. Therefore, cutting tools must be carefully manufactured and ground. Especial care is required in the production and maintenance of complex tools and form tools for finishing operations.

Finished work is checked with measuring tools selected to suit the required accuracy. If an accuracy up to 0.1 mm is required, a vernier caliper is used both for external and internal dimensions. For an accuracy within 0.01 mm, a micrometer is employed.

Work machined on automatic and semi-automatic lathes is usually inspected by plug and snap limit gauges. These tools are based on the principle of checking a dimension, not by measuring its actual size, but by determining whether the actual size is within the permissible limits (see Fig. 85).

If, for example, the nominal size is 20 mm and the tolerance is—0.10 mm, all parts with diameters from 19.9 to 20 mm will be within the specified tolerance. In this case, a snap gauge for this part will have two dimensions, 19.9 and 20.0 mm, at the two sides. The side with the 20 mm dimension should pass over all parts within the tolerance. This is called the GO side. The other side with the 19.9 mm gap is called the NOT-GO side and will not pass over parts that are within the tolerance limits.

If a hole of the same size is inspected, the ends of the plug limit gauge will have the same two sizes as above except that 19.9 mm will be the GO end and 20 mm—the NOT-GO end.

Measuring instruments (see Fig. 86) are convenient and highly productive for certain types of inspection. They are widely used in Soviet engineering plants.

Measuring tools and instruments require most cautious handling. They should be carefully oiled and wiped dry. Large forces must never be applied to measuring tools and instruments. They should be thoroughly checked at definite periods according to a schedule.

§ 71. CAUSES AND PREVENTION OF SPOILAGE

Table 14 lists the most frequently encountered types of spoilage, their causes and methods of their prevention.

Table 14

Types, Causes, and Prevention of Spoilage

Type of spoilage	Causes	Methods of prevention
1. Out-of-roundness of external or internal diameter.	a) Work spindle runs out of truth.	a) Adjust spindle bearings and eliminate runout.
	b) Spindle bearings are worn or incorrectly mounted.	b) Worn sleeve bearings are to be rescraped and spindle rotation is to be adjusted. If anti-friction bearings are worn, check their mounting. Excessively worn bearings with large clearances should be replaced.

(Continued)

Type of spoilage	Causes	Methods of prevention
	c) Allowance is not uniform on the blank.	c) Improve the blank, decrease eccentricity, increase the rigidity of the slide.
	d) Inaccurate (eccentric) centring.	d) Eliminate defects in centring.
	e) Distortion of work by chuck jaws.	e) Adjust clamping force.
2. Taper in external cylindrical surface.	a) Lack of parallelism of longitudinal slide ways or lack of squareness of cross slide ways with spindle axis.	a) Eliminate lack of parallelism or lack of squareness of slide ways.
	b) Defect in setting broadnose tool in cross slide.	b) Correct tool setting.
	c) Headstock and tailstock centres not in alignment.	c) Eliminate misalignment and check alignment of centres.
	d) Workpiece is set up incorrectly or possesses insufficient rigidity.	d) Eliminate deflection of overhanging work pieces by supporting end with centre or in steadyrest (or rollers).
	e) Tool wear (for long work).	e) Use carbide tipped tools.
3. Taper in a hole.	a) Same as for external tapers.	
	b) Core drill, twist drill or reamer is incorrectly set up.	b) Adjust tool into alignment with spindle axis.
4. Face surface not square with axis of work.	a) Inaccuracy of the machine.	a) Eliminate lack of squareness of cross slide ways.
	b) Cutting tool is incorrectly set up.	b) Set up spotfacer in proper alignment on end-working (longitudinal) slide.

Type of spoilage	Causes	Methods of prevention
	c) Incorrectly clamped work or lack of rigidity of work spindle.	c) Align clamping device, eliminate excess clearance in spindle bearings and distortion of work in clamping device.
	d) Insufficient width of cut-off tool.	d) Use wider cut-off tool.
5. Barrel form (larger diameter in middle of cylindrical su face).	Insufficient rigidity of the work.	Eliminate deflection of the work (use a steadyrest, roller or other support).
6. Variations in diameter of external and internal surfaces of the work.	a) Excessive clearances in spindle bearings and slide ways.	a) Adjust spindle bearings; adjust taper and flat gibs of slides.
	b) Rapid tool wear.	b) Check tool angles and grinding; use carbide tipped tools.
	c) Bending of single-point tools in the holder	c) Reduce tool overhang in the holder.
	d) Machining allowance varies for different blanks	d) Tighten spindle bearings, reduce clearance in slide ways, use more rigid tool holders and cutting tools.
	e) Stops "give" or are incorrectly set up.	e) Reduce overhang and adjust stops, tighten clamping bolts of the stops.
	f) Poorly clamped cross slide feed cams.	f) Check and clamp cams rigidly.
	g) Inaccurate indexing and locking of spindle carrier.	g) Check and adjust the locking mechanism.
	h) Excess load on finishing tool.	h) Reduce depth of cut for finishing tool by increasing depth of cut for the roughing tool.

(Continued)

Type of spoilage	Causes	Methods of prevention
7. Variations in axial dimensions of the work.	a) Axial slip in spindle bearings.	a) Draw up thrust bearings.
	b) Axial slip in spindle carrier.	b) Draw up or rescrape gibs of spindle carrier.
	c) Rebound or overrun of bar stock being fed to the stop.	c) Adjust stock feeding mechanism. Reduce overhang of stock stop.
	d) Poorly clamped longitudinal feed cams.	d) Clamp cams rigidly.
	e) Insufficiently clamped bar stock.	e) Adjust stock chucking mechanism.
8. Misalignment of hole axis.	a) Misalignment of axes of hole machining tool and work spindle.	a) Check alignment and make the required adjustments.
	b) Cutting forces of tools for machining external and internal surfaces are directed oppositely (clearance is taken up in opposite directions).	b) Machine internal and external surfaces simultaneously.
9. Errors in form surfaces.	a) Distortion of work by clamping.	a) Reduce clamping force. Change operation sequence; change clamping force before finishing operation.
	b) Circular form tool set up incorrectly.	b) Set circular tool to centre.
	c) Workpiece lacks rigidity.	c) Alter design of chucking device.
10. Rough surface.	a) Tool nose radius too small.	a) Increase nose radius or use tool form devised by V. A. Kolesov.
	b) Dull cross cutting tool.	b) Grind and lap cross cutting form tool.
	c) Incorrect tool cutting angles.	c) Grind tool to suit material being machined.
	d) Incorrect cutting fluid.	d) Select cutting fluid as per instructions.

(Continued)

Type of spoilage	Causes	Methods of prevention
11. Chatter marks on machined surface.	a) Tool vibration due to setting off centre, poor clamping, large overhang of tool, large tool width for small speed.	a) Set tool on centre, clamp firmly, reduce overhang, increase cutting speed.
	b) Work vibration due to lack of rigidity or incorrect clamping.	b) Reduce distance between work supports, reduce overhang of work and chip cross-section. Use a steadyrest.
	c) Vibration of machine units due to excessive clearances in bearings and ways.	c) Eliminate excess clearances.
12. Surface marred by helical line.	Tool cuts helix when it is withdrawn.	Set tool slightly above centre for external and slightly below centre for internal surfaces.
13. Thread is cut off by tool.	a) Heavy spring in thread-cutting attachment; thread is cut off at very start.	a) Release spring somewhat.
	b) Tool feeds faster than the thread.	b) Lower curve off cam for cutting and running out of thread.
	c) Spindle is reversed incorrectly.	c) Adjust cam to properly time spindle reversal.
14. Torn thread.	a) Incorrect cutting angles on thread-cutting tool.	a) Grind tool to suit material being machined.
	b) Wrong cutting fluid.	b) Change cutting fluid.
15. Teat is left on work after cutting off.	Cut-off tool is set incorrectly: 1) does not reach centre of work, 2) above or below centre.	Set tool correctly.

Part Three

DESIGN OF REPRESENTATIVE AUTOMATIC AND SEMI-AUTOMATIC LATHES AND HOW THEY ARE SET UP

CHAPTER I

AUTOMATIC CUTTING-OFF MACHINES AND SWISS-TYPE AUTOMATIC SCREW MACHINES

§ 72. MACHINING SEQUENCE FOR AUTOMATIC CUTTING-OFF MACHINES

Automatics of this type are designed for the mass and large lot production of comparatively short work from 3 to 20 mm in diameter (Fig. 96).

Several models of these automatics are manufactured in the Soviet Union. Some operate on bar stock while others use coils of wire.

Both coil- and bar-type automatics are among the simplest machine tools designed for forming and cutting off comparatively short workpieces with cross-feeding tools (see Fig. 13). Longer work, in which only the ends are machined, may be effectively produced by form-turning the rear end of one workpiece together with the front end of the next workpiece (Fig. 97). Special attachments are employed if holes or thread are required on simple parts. The bar stock is fed out with a cam mechanism and a feeding tube and finger actuated by a spring or a weight. The bar is fed out to the full length of the work plus the width of the cut-off tool.

The machining sequence for automatic bar-type cutting-off machines is designed to comply with the following cycle of machine operations:

1) Stock stop advance to the working position on the line of centres, 2) stock feed to the stop, 3) stock chucking, 4) stock stop withdrawal, 5) rapid approach of the toolslides, 6) working feed of the toolslides, 7) rapid return of the toolslides, and 8) release of the stock.

In accordance with the construction of the automatic and the time required for the various auxiliary operations, items 4 and 5, and 7 and 8 may overlap completely or to some extent.

Table 11 illustrates a typical example of part machining on the coil-type automatic. In these machines (Fig. 98), turning is performed by single-point tools which rotate about the axis of the stationary workpiece, clamped at three places by the front and rear chucks and a spring collet inside the machine spindle.

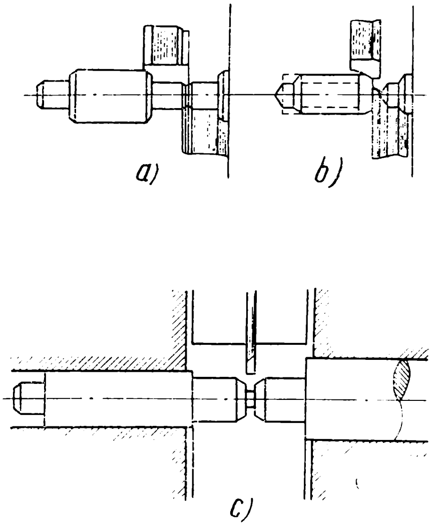


Fig. 97. Tooling layouts for automatic cutting-off machines.

a and *b* — on a bar-type automatic, *c* — on a coil-type automatic.

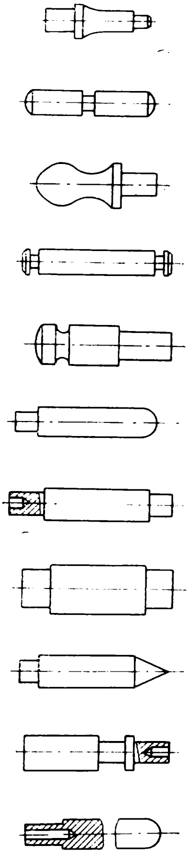
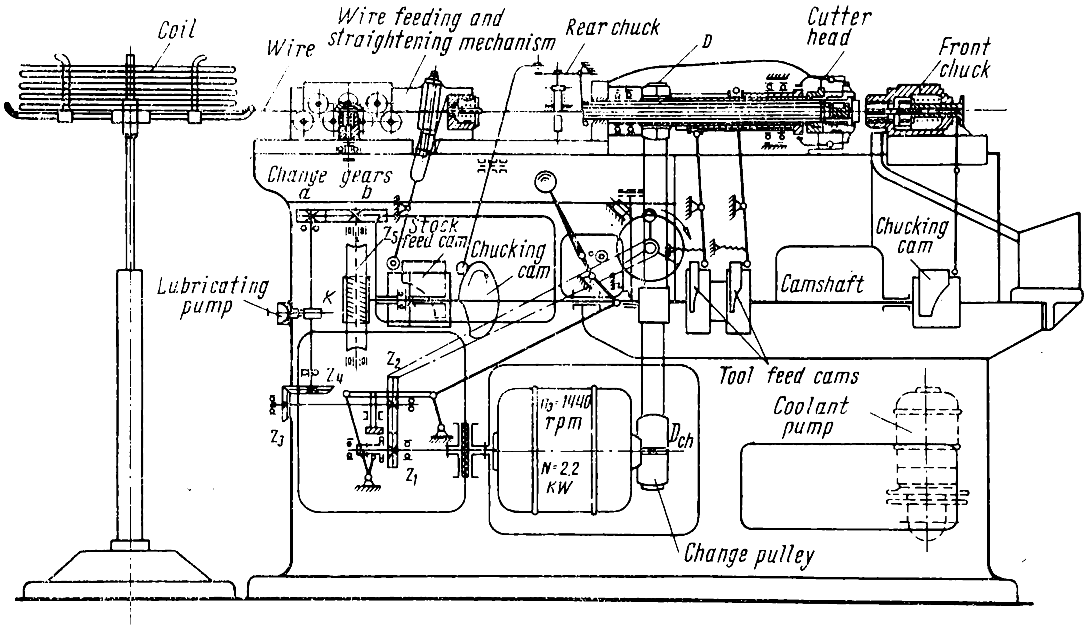


Fig. 96. Typical work machined on automatic cutting-off machines.

§ 73. AUTOMATIC CUTTING-OFF MACHINE, MODEL 1106

The automatic cutting-off machine, model 1106, (Fig. 98) is a single-spindle coil-type automatic. It can be used for producing parts of round, hexagon, or square wire. It will accommodate work up to 8 mm in diameter and 100 mm in length.

As differing from automatics which turn work of bar stock, the wire stock in model 1106, loaded into the machine in a coil, does not rotate during operation. It is held (see Fig. 98) by three chucking devices (rear chuck, front chuck, and the spring collet in the spindle) while the cutting tools, mounted in a rotating cutter head (Fig. 99), are fed crosswise at feeds independent of each other. While the work is being machined, the slide with seven rollers travels from right to left, straightening the next length of wire. When the turning is finished and the work is cut off, the tools in the cutter head withdraw, the chucking devices open, and the straightener slide, travelling



F i g. 98. Gearing diagram of the automatic coil-type cutting-off machine, model 1106.

$$n_s = n_m \frac{D_{ch}}{D} \text{ rpm}; \quad n_{cs} = n_m \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{a}{b} \times \frac{k}{Z_5} \text{ rpm};$$

$$1 \text{ revolution of the camshaft } \frac{Z_5}{k} \times \frac{b}{a} \times \frac{Z_4}{Z_3} \times \frac{Z_2}{Z_1} \times \frac{D_{ch}}{D} = n_{cycle};$$

$\frac{a}{b} = \frac{A}{n_{cycle}}$ in which: $A = \frac{D_{ch}}{D} \times \frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} \times \frac{Z_5}{k}$; k is the number of threads on the worm; n_{cycle} is the number of spindle revolutions to make one piece.

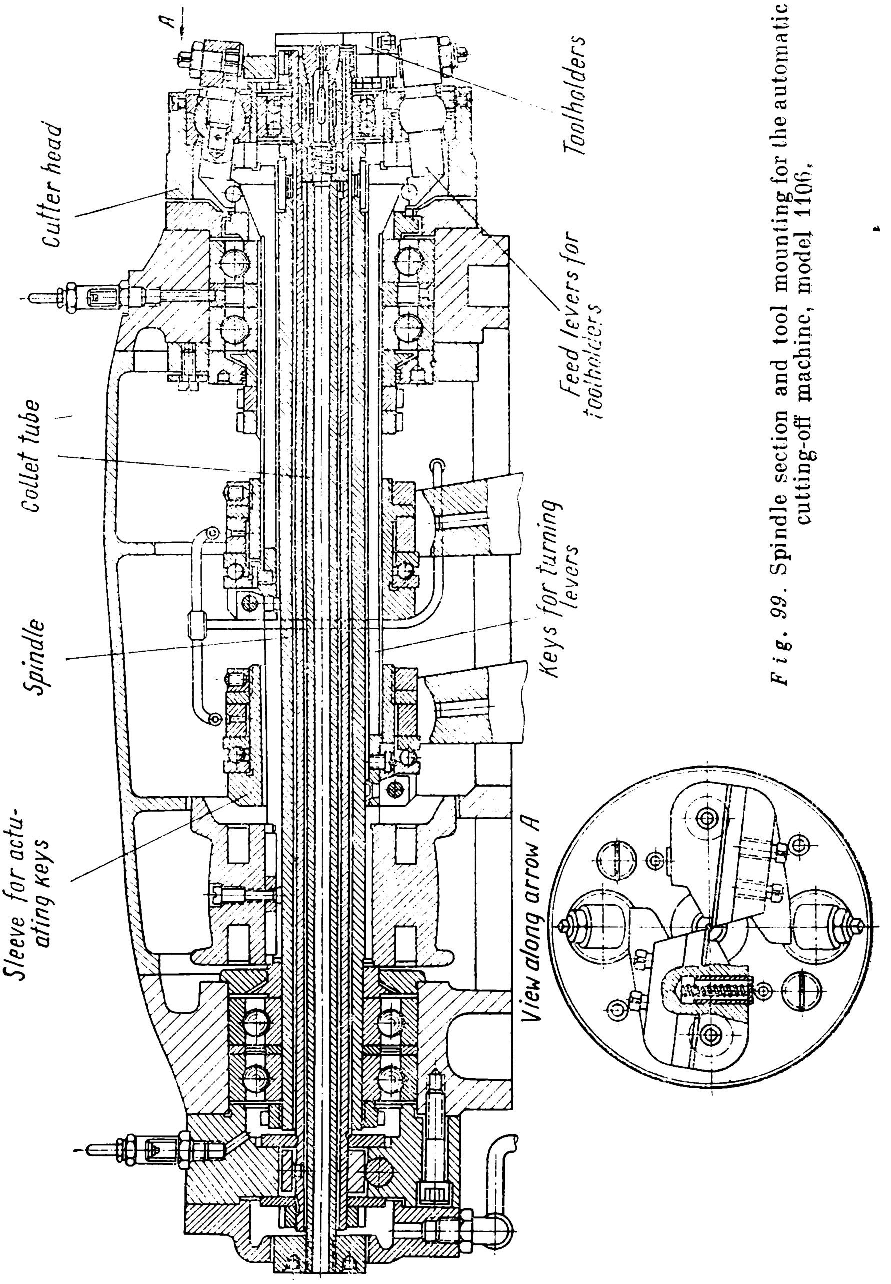


Fig. 99. Spindle section and tool mounting for the automatic cutting-off machine, model 1106.

from left to right, feeds out the wire stock on the preset length, pushing the preceding workpiece out of the front chuck.

All movements of operative and auxiliary units are actuated from the camshaft whose speed is set up by change gears. The spindle with the cutter head is driven from the motor through a flat belt. The camshaft is powered from the same main-drive motor through spur and bevel gearing, change gears and worm gearing. Cams mounted on the camshaft and their purposes are shown in Fig. 98.

Model 1106 automatics are high production machines which operate almost silently since the stock does not rotate as in bar machines. The machine operates with high accuracy and the end of the work is trimmed off leaving no teat in cutting off. This is due to the fact that the workpiece remains clamped until it is completely severed from the wire stock.

Setting up these machines is a simple procedure, adjustments and resetting are seldom required since a very large number of pieces may be made of one coil of wire.

In planning the tooling layout, the processing engineer must try to have all the roughing done by one tool and finishing by the other. Cutting off is best performed at the end of the finishing cut. Since the workpiece is clamped on both sides of the machining zone, the work is layed out so that the rear end of one workpiece is turned simultaneously with the front end of the next.

A tooling layout and operation sheet for turning a centre on the model 1106 automatic are given in Table 11.

The wire stock is fed out an amount equal to the length of the work (12 mm) plus 0.8 mm for the cut-off.

§ 74. MACHINING SEQUENCE FOR SWISS-TYPE AUTOMATIC SCREW MACHINES

On Swiss-type automatics, machining is performed by stationary or cross-fed single-point tools in conjunction with longitudinal working feed of the bar stock. As a rule, turning takes place directly at a guide bushing or steadyrest supporting the stock. Longitudinal feed is obtained by movement of the headstock or of a quill carrying the spindle. Stepped, tapered, and formed surfaces may be obtained by a combination of cross and longitudinal movement without using special form tools.

Swiss-type automatics are designed chiefly for turning long stepped work of complex form (Fig. 100) from 4 to 25 mm in diameter.

High machining accuracy is a feature of Swiss-type automatics. With proper maintenance, an accuracy up to ±0.005 mm may be attained but practical repeated accuracy is within 0.01-0.02 mm for diameters and 0.02-0.03 mm for length dimensions.

Special requirements are made to bar stock quality, for these automatics, to ensure high work accuracy. Bar stock should be first ground on a centreless grinding machine. This recommendation will ensure a diameter accuracy of 0.01 to 0.02 mm in accordance with the size of the stock.

Many special features are involved in Swiss-type automatic turning operations (see Fig. 18). Cylindrical surfaces are turned by tools clamped in the front and rear lower (rocker-arm) toolslides. Precise cylindrical surfaces are always turned by a tool which is held against a positive stop during the cut (after the cross approach movement).

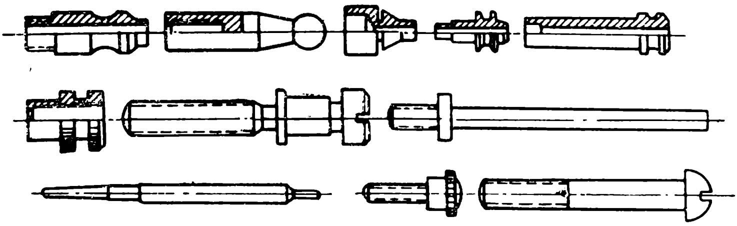


Fig. 100. Typical parts produced by Swiss-type automatics.

Narrow cylindrical surfaces or recessed surfaces may be turned by cross-fed tools without longitudinal bar feed (stationary headstock).

In cases when the machined surface is far from the guide bushing or steadyrest, the front end of the work should be turned with longitudinal movement at a comparatively low rate of feed. The use of a wide-nose tool in this case will spring the work, causing error in the diameter. It will also cause heavy vibration and, consequently, a poor surface finish on the work.

Stepped cylindrical external machining may be performed by a single tool. Before the headstock or spindle quill is fed, the tool approaches the position for the smallest diameter and remains stationary until the first step is completed. After this, the headstock stops (or is even retracted slightly) while the tool is withdrawn to a new position corresponding to the diameter of the second step. Then the headstock is again fed forward by the length of the second step, etc.

Form tools may be used for turning narrow sections near to the guide bushing. Formed and tapered surfaces turned with these tools will be less accurate and have a poorer surface finish than surfaces machined by the second method (with longitudinal feed).

Machine parts often have grooves or shoulders with small recesses or internal tapers on a face surface (see position 8, Fig. 18). These are machined by feeding in the tool with the headstock stationary. Then the headstock is fed forward or backward by the required amount.

After turning the tapered recess, the headstock is reversed to retract the tool from the recess so that it can be withdrawn from the work.

Small holes are drilled by one-, two-, or three-position attachments, with or without drill rotation.

The drill is often rotated in the reverse direction to increase the cutting speed.

The main requirement to obtain accurate holes is that the work and drill axes exactly coincide. For this purpose, a spotting operation should precede the drilling. Shallow holes may be drilled without spotting. Drilling is best performed at the beginning of the operation when the work does not project far out of the guide bushing or steadyrest.

In deep-hole drilling, the drill is withdrawn periodically to remove chips and to cool the drill. As the hole becomes deeper, the drill is more frequently withdrawn. A deep-drilling cycle of this type is obtained by a corresponding design of the drilling attachment cam.

Thread is usually cut with rotation of the work and the cutting tool in the same direction. The relative speed of rotation, which determines the cutting speed, is the difference between the work and tool speeds. Tool speed exceeds the work speed for cutting right-hand thread (tool leads the work). For left-hand thread, the cutting tool must lag (rotate slower than the work).

The finished work is cut off by feeding in the cut-off tool with the headstock stationary. After cutting off, the cut-off tool is often used as a stock stop to feed out the bar.

§ 75. SWISS-TYPE AUTOMATIC SCREW MACHINE, MODEL 1A10П

The model 1A10П automatic comprises the following principal units (Fig. 101): base and drive, bed with ways along which the headstock travels at the right-hand side, tool frame with three upper (overhead) toolslides and a double lower toolslide or rocker arm, supplementary tooling devices, as well as units for loading and stock chucking.

Gear Trains (Fig. 102). Rotation is transmitted from the 1.7 kw 3-phase induction motor (1,420 rpm) through the change pulleys D_A and D_B to the main transmission shaft *I*. A long plain aluminium pulley, 120 mm in diameter, is mounted on this shaft. From it, rotation is transmitted through a flat belt to the 60 mm pulley on the work spindle. A long pulley enables the belt to shift during headstock travel. The motor belt is tensioned by adjustment of the motor base while the spindle drive belt is tensioned by an idler pulley.

The spindle speed is determined by the formula:

$$n_s = n_m \frac{D_A \times 120}{D_B \times 60} = 1{,}420 \frac{D_A \times 120}{D_B \times 60} = 2{,}840 \frac{D_A}{D_B} \text{ rpm},$$

in which n_m is the motor shaft speed in rpm;

D_A is the diameter of the motor pulley in mm;

D_B is the diameter of the transmission shaft pulley in mm.

Table 15

Breif Specifications of Swiss-Type Automatic Screw Machines

Item	Unit	Model					
		110	112	110П	1A10П	1П12	1125
Bar capacity	mm	7	12	7	7	12	25
Maximum workpiece length (max. stock feed)	mm	70	80	50	50	80	150
Maximum bar length	m	3.5	3	3	2	3	3.5
Number of toolslides:							
On tool frame		2	2	3	3	3	4
On rocker arm		2	2	2	2	2	—
Drilling capacity in steel	mm	5	8	4	4	8	12
Maximum thread cut in steel	mm	6	8	5	5	8	12
Range of spindle speeds	rpm	1,150 to 7,800	100 to 7,670	890 to 6,000	1,030 to 6,250	800 to 6,300	300 to 4,000
Cycle time range (time to make one piece)	sec	0.8 to 133	1.9 to 330	1 to 216	1 to 273	1.75 to 500	6 to 1,140
Motor power	kw	2.2	2.8	1.7	1.7	2.8	4.6
Overall dimensions:							
Floor space occupied	mm	1,300×600	1,410×570	1,700××650	1,250××810	1,465××870	1,905××1,000
Height	mm	1,500	1,500	1,400	1,430	1,365	1,427
Approximate net weight	kg	1,000	1,100	1,000	550	800	1,800

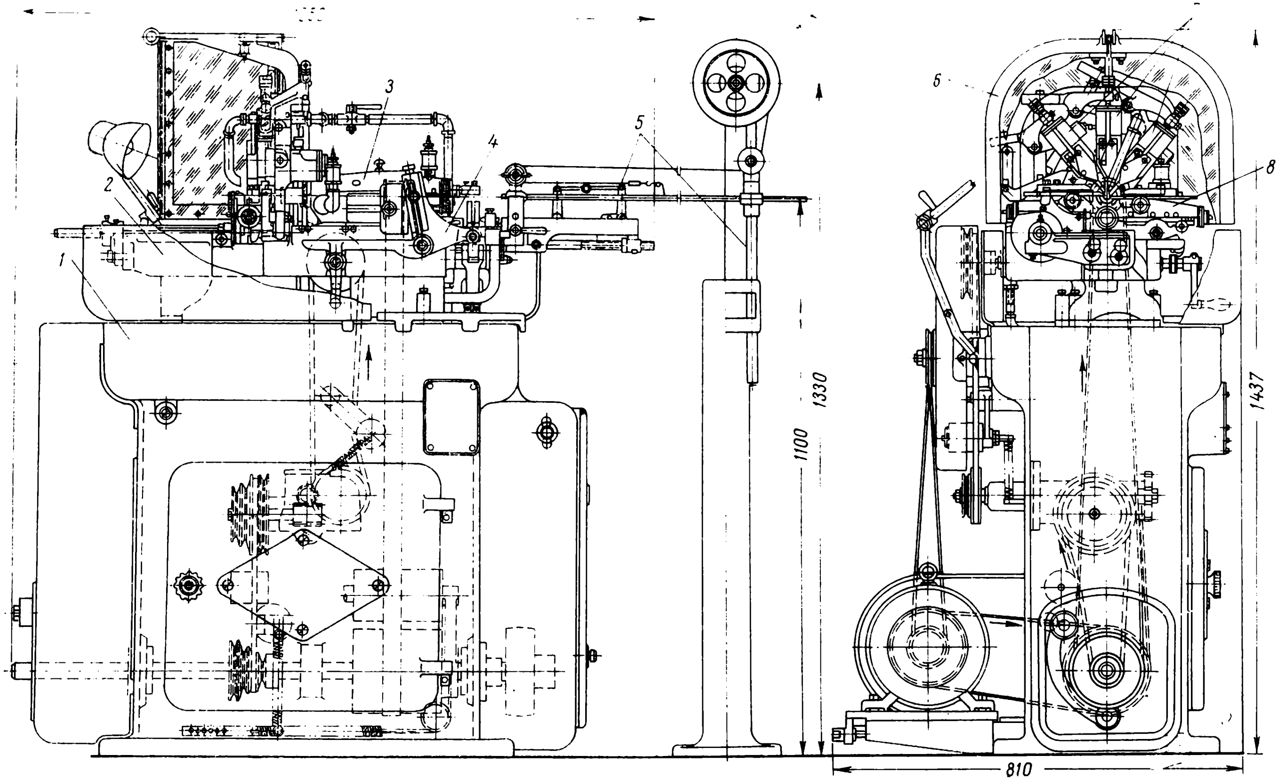


Fig. 101. Swiss-type automatic screw machine, model 1A10П.

1 — base, 2 — bed, 3 — headstock, 4 — headstock travel mechanism, 5 — stock feed unit, 6 — guard, 7 — three upper toolslides, 8 — two rocker arm toolslides.

The camshaft is driven through the following gear train: from a section *C*, *D*, *E*, or *F* of the four-step pulley on the transmission shaft, rotation is transmitted by a V-belt to the corresponding section, *G*, *H*, *I*, or *J* of the pulley mounted on shaft *II* of the worm reducing gear. From this shaft, rotation is transmitted further through worm gearing, change gears *a* and *b*, belt drive, *L*, *M-N*, *O* (on shafts *III* and *IV*), and a second worm gearing arrangement to the camshaft *V*. This gear train is engaged by a claw clutch on the shaft of the second worm. Another claw clutch and a crank handle are mounted on shaft *IV* which passes through the hollow worm shaft. When the lever with the shaft is shifted away from the operator, power feed is disengaged and hand feed is engaged.

The drilling and threading attachment spindles, slotting and other attachments are driven through a belt from a pulley mounted on the transmission shaft.

The camshaft speed is set up by means of the change pulleys D_A and D_B, by shifting the belt on the stepped pulleys, and by the change gears *a* and *b*. The cycle time and the rate of production are determined by the formulas

$$T_c = \frac{60}{n_{cs}} \text{ sec}; \quad Q = n_{cs} \text{ pcs per min};$$

$$Q_a = n_{cs}\,\eta \text{ pcs per min}.$$

General Arrangement. The automatic has a box-shaped cast-iron base. The base encloses the main drive with the motor mounted on an adjustable plate secured to the rear wall. Adjustment of the plate provides for proper tension of the flat belt from the motor to the transmission shaft. The cutting fluid tank is located in the left-hand part of the base while an electrical equipment cabinet is arranged in the upper right-hand section. The upper part of the base serves as a chip pan. The transmission shaft is also mounted in the base.

The worm reducing gear, secured to the rear inside wall of the base, transmits rotation to a transverse shaft and further through change gears to a second shaft which mounts a two-step pulley on its left end. From here, rotation is transmitted further through worm gearing to the camshaft.

The bed, mounted on the base, has ways at the right-hand end for headstock travel. The tool frame is fastened on the upper surface of the bed which mounts the various attachments at the left. The camshaft is mounted at the back of the bed. It carries the worm wheel which is driven by a worm. A shaft passing through the worm has a crank handle on one end for hand feed and a two-step pulley with a claw clutch on the other end for power feed. When this shaft is shifted toward the operator, the claw clutch meshes with the clutch teeth on the face of the worm and the camshaft begins rotating. Hand feed is engaged by pushing the shaft in the opposite direction. In this case the hand feed crank handle is engaged to the worm.

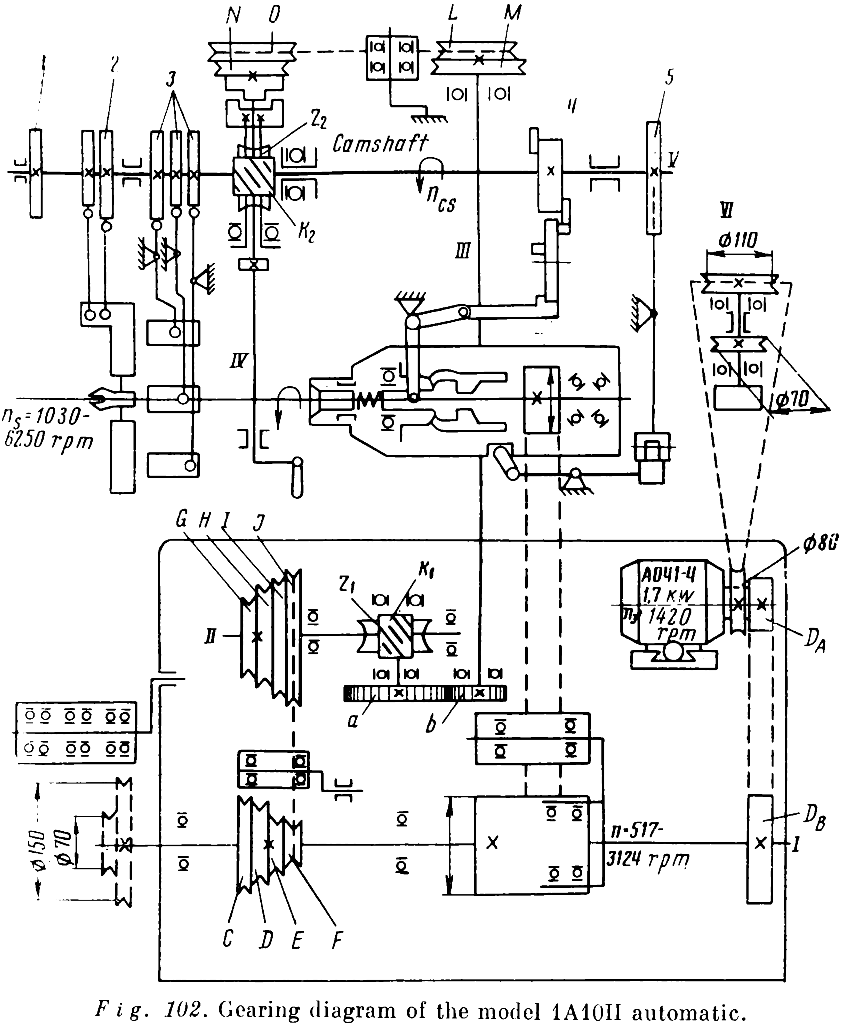


Fig. 102. Gearing diagram of the model 1A10II automatic.

(Cams: *1* — for attachments, *2* — for rocker arm, *3* — for upper toolslides, *4* — for stock chucking, *5* — for headstock travel):

$$n_s = n_m \frac{D_A}{D_B} \times \frac{120}{60} = 1,420 \frac{D_A}{D_B} \times \frac{120}{60} = 2,840 \frac{D_A}{D_B} \text{ rpm};$$

$$1 \text{ revolution of the camshaft } \frac{Z_2}{k_2} \times \frac{D_4}{D_3} \times \frac{b}{a} \times \frac{Z_1}{k_1} \times \frac{D_2}{D_1} \times \frac{120}{60} = n_{cycle};$$

$$\frac{a}{b} = \frac{2A}{n_{cycle}}; \quad A = \frac{Z_2}{k_2} \times \frac{D_4}{D_3} \times \frac{Z_1}{k_1} \times \frac{D_2}{D_1}$$

in which $\frac{D_1}{D_2}$ is one of the pulley diameter ratios $\frac{C}{G}$, $\frac{D}{H}$, $\frac{E}{I}$, or $\frac{F}{J}$;

$\frac{D_3}{D_4}$ is one of the pulley diameter ratios

$\frac{M}{N}$ or $\frac{L}{O}$.

A plate cam for headstock feed and a drum with cams for actuating the chucking device are mounted on the right end of the camshaft. The cams may be set up on the drum in an annular T-slot to suit the required cycle. Plate cams for controlling the overhead toolslides and the rocker arm are mounted at the left end of the camshaft. Radial slots in the overhead toolslide cams facilitate quick cam changing.

An equal-arm lever on the right end face of the bed transmits motion to another lever *4* (Fig. 101) with a roller on its end. Motion is transmitted from this roller to a shoe secured to the headstock.

The roller can be adjusted along a vertical slot to change the arm ratio of the lever from 1 : 1 to 3 : 1. This adjusts the length of headstock travel.

Headstock (Fig. 103). The bar stock, held in the rotating spindle, obtains its longitudinal feeding motion from headstock travel.

The base of the headstock housing is of dovetail form and slides in the bed ways. Longitudinal feed of the headstock is effected by a plate cam through a lever system. Rapid withdrawal of the headstock to its initial position is actuated by spring action.

The spindle is driven by a flat belt. Its front support is a plain bronze bearing, the rear support comprises two angular contact ball bearings of class A accuracy. The front bearing is mounted on a taper bore of the headstock housing. The required oil-filled clearance is obtained by adjustment with nuts. Excess clearance in the ball bearings is also eliminated by a nut.

Stock is chucked by a slotted rocker arm and a sliding block linked to an arm of a shifting fork. The ends of the fork shift a sleeve with a ball bearing. The latter moves a tapered bushing along the spindle to spread the ends of the collet operating levers.

These levers, located in slots of the spindle, shift the collet sleeve through the collet tube. In its forward movement, the collet sleeve, having an internal taper, closes the spring collet firmly on the bar. The collet sleeve is shifted in the other direction by spring action. The clamping force of the chuck is adjusted by a nut which is locked in the required position by a screw.

The internal end face of the spindle nose cap is the bearing surface of the spring collet. The collet is changed by unscrewing the cap.

The bearing surfaces of the dovetail ways are lubricated with a gun through ball-type fittings.

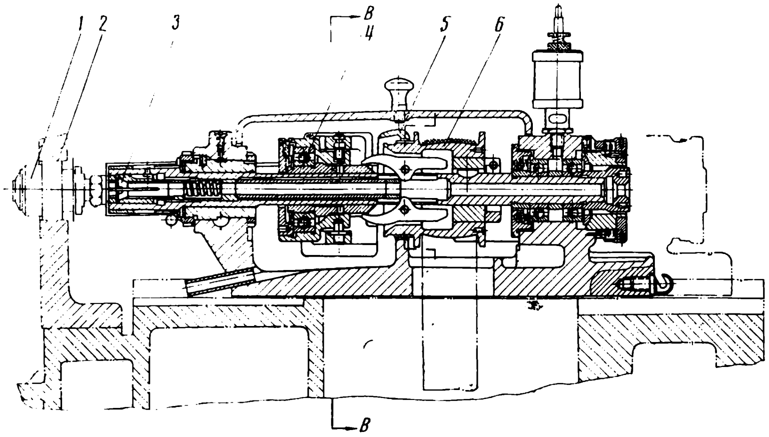
The front and rear bearings are lubricated by wick-feed oilers mounted in the headstock housing.

All other points of lubrication are served by ball-type oilers.

The tool frame (Fig. 104) is a casting which carries the three overhead toolslides (see also Fig. 37 *b*).

The three slides are of identical design. Each consists of a cast-iron body with dovetail ways and a cylindrical shank. The latter fits a bore in the tool frame casting. The slides proper, with the toolholders, travel along the ways of the slide bodies. Tools are clamped

Section AA



Section BB

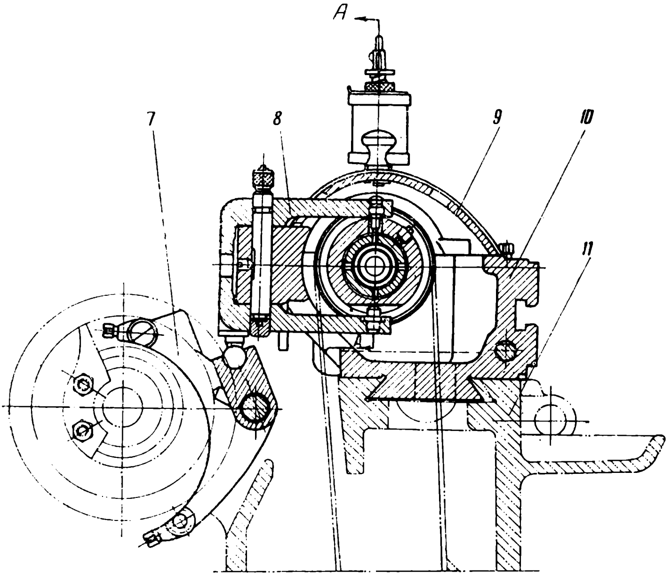


Fig. 103. Headstock of the model 1A10П automatic.

1 — bore for the steadyrest bushing assembly, *2* — tooling frame, *3* — spring collet, *4* — collet operating sleeve, *5* — collet operating levers, *6* — spindle drive pulley, *7* — lever system of fork *8* for actuating levers *5* *9* — upper cover, *10* — headstock housing sliding in dovetail ways of the bed *11*.

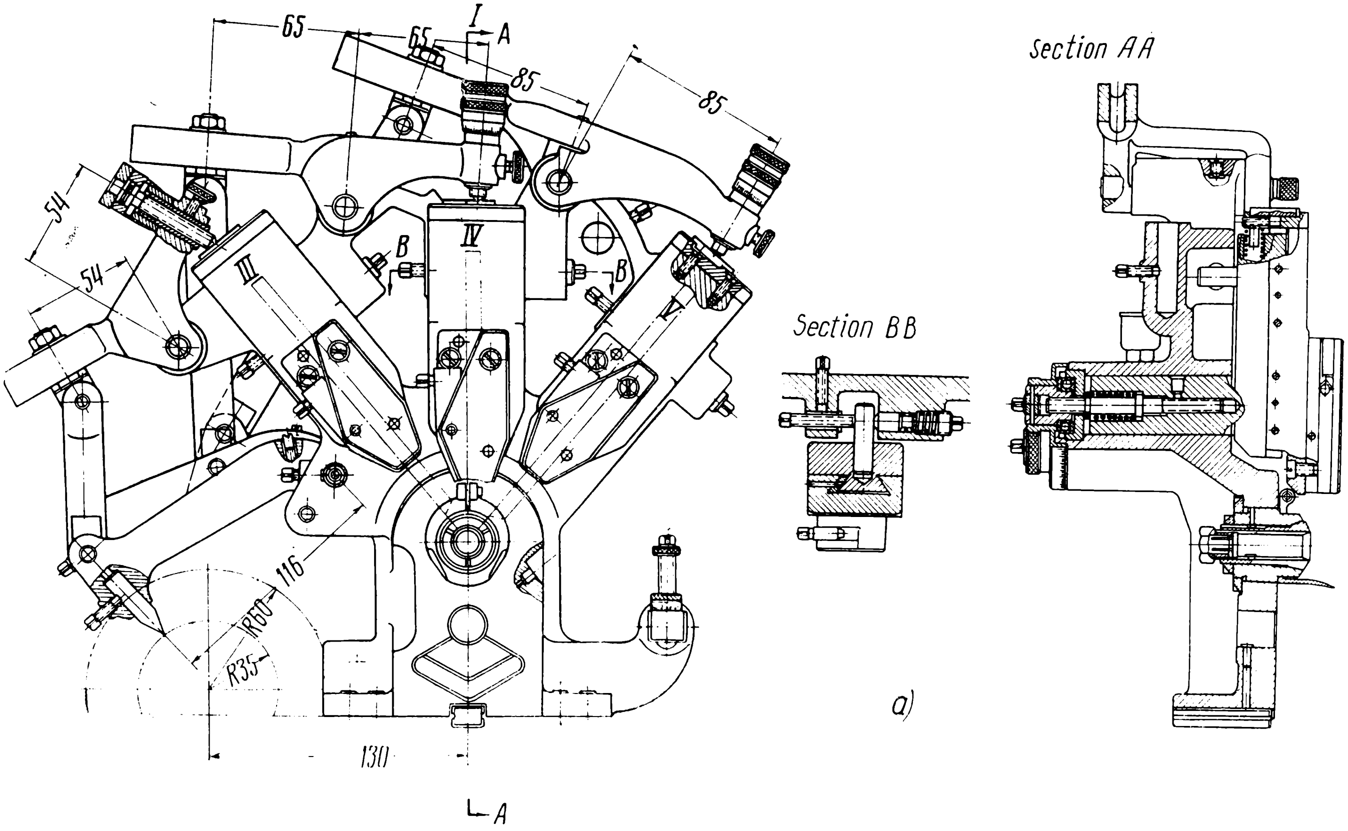
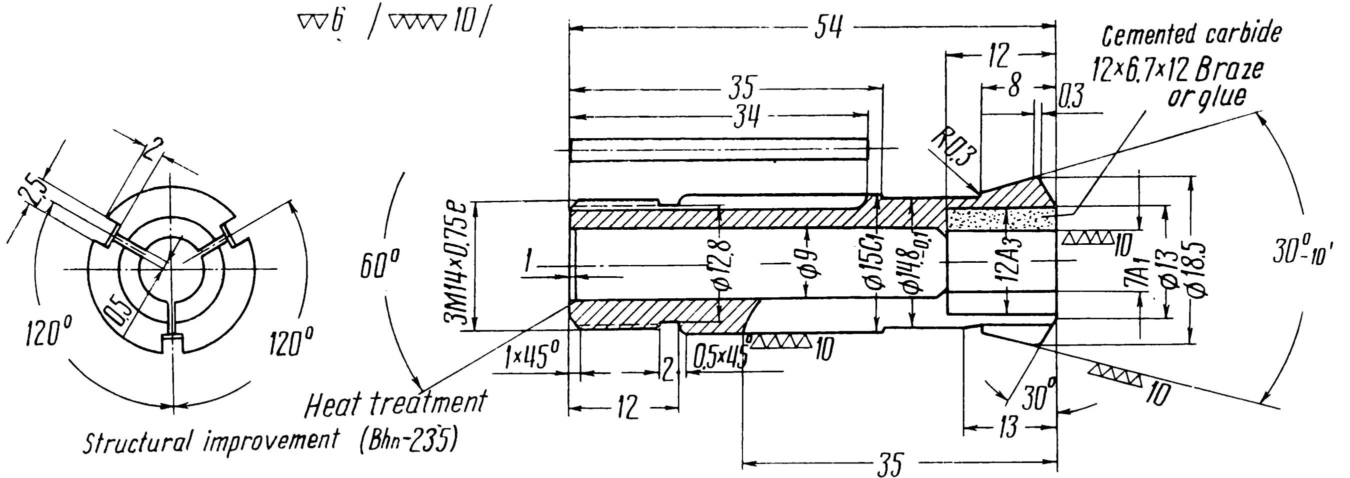


Fig. 104,a. Toolslides *III*, *IV*, and *V* of the model 1A1011 automatic.



Manufacturing Specifications

1. Out-of-roundness and taper of ø7A shall be within 0.002mm
2. Runout of taper 30° and cylinder ø15 in reference to hole ø7A shall be within 0.015mm on a length of 12mm from the end face
3. Runout of cylinder ø15 in reference to taper 30° shall be within 0.015mm.
4. Out-of-roundness and taper of ø15 C1 shall be within 0.002mm

b)

Fig. 104,b. Steadyrest bushing.

in the holders with a screw and a swinging clamp. The cutting tool has three adjustments: to the depth of cut (by an adjusting screw and dial graduated in 0.01 mm divisions), along the axis of the work, and to the centre of the work.

The feed motion of each vertical (overhead) tool is obtained from a plate cam through a system of levers. Toolslides are retracted by springs.

A slide block may be adjusted along a slot of one of the feed levers to obtain lever arm ratios from 2 : 1 to 1 : 1 and to change the slide travel in this manner.

The stationary steadyrest is located in the centre of the tool frame. It aligns and supports the bar stock.

The steadyrest comprises a taper sleeve, inserted in a bore of the tool frame, which accommodates a split, externally-tapered bushing. A split liner of cemented carbide, grade BK-8, with a lapped inside surface, is brazed into the hole in the bushing.

Rocker arm. The double toolslide or rocker arm (Fig. 105) is pivoted on a taper pin in the lower part of the tool frame (see also Fig. 37 *a*). Cutting tools may be set up to the centre of the work and to the required depth of cut.

A bracket, fastened to the rocker arm, has follower toes that contact plate cams on the camshaft. A spring holds the toes tightly against the cams. An adjustable positive stop, arranged on the right-hand end of the rocker arm, enables a highly accurate size to be obtained in turning operations.

The device for feeding out the bar stock is also designed to hold the bar against a stop when the headstock is retracted. It consists of a column, stock tube, and a hinged bracket.

The column housing (see Fig. 101) mounts a rod which carries an axle with rollers and a bracket. The latter supports the stock tube.

The hollow column contains a weight hung on the end of a wire rope wound on a roller. Another wire rope, passing through the rollers, is secured to the side-pin of the stock pusher. Thus, the weight forces the pusher along the stock tube.

The stock tube has a longitudinal slot into which the pusher side-pin enters. The side-pin bears against the end of the bar stock and holds it against the stop when the chuck is open and the headstock is being retracted. The cut-off tool serves as the stock stop in this case.

When the whole length of bar stock is used up, the pusher side-pin approaches the pin of a lever. The other end of this lever trips the button of a microswitch when the lever is turned by the pusher. This switches off the main drive motor.

In restocking the automatic, the bracket, in which the end of the tube is held, is swung to the side so that the butt end of the stock can be removed and a new bar inserted.

The coolant system consists of the pump and pipeline. Cutting fluid is delivered from the tank to the cutting tools by the pump

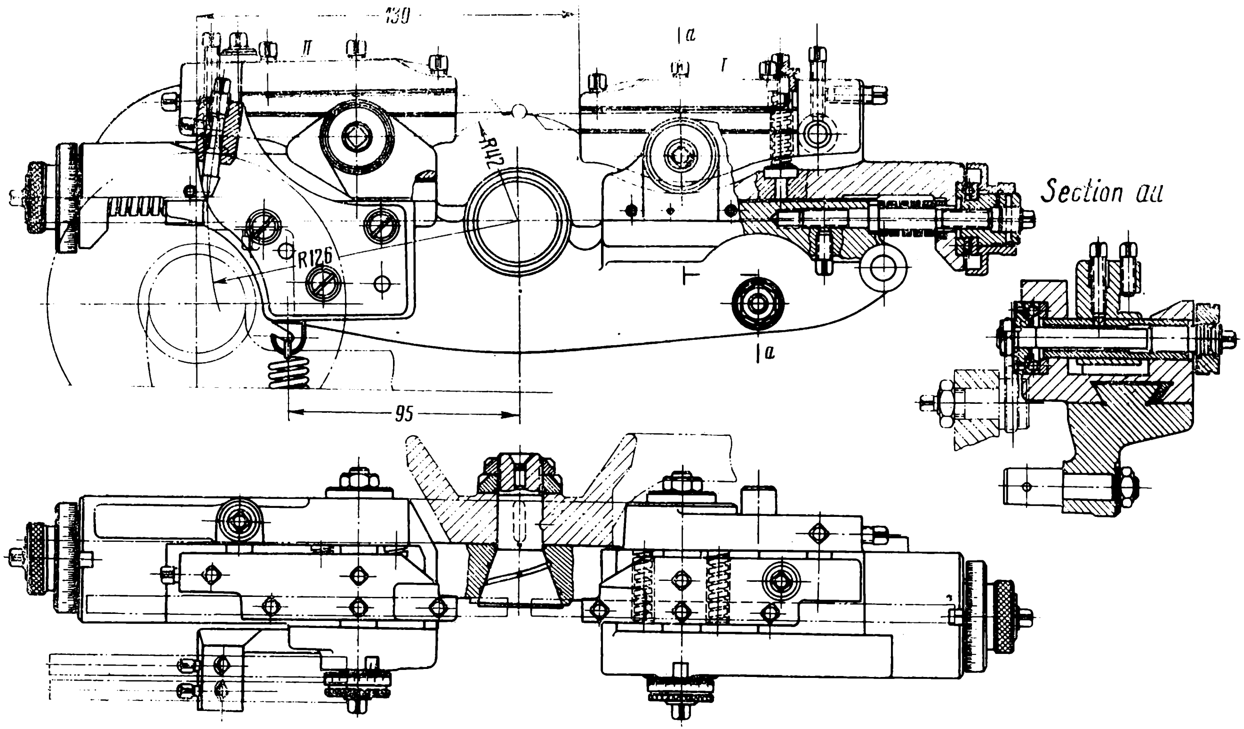


Fig. 105. Rocker arm toolslides (*I*, *II*) of the model 1A10П automatic.

secured to the machine base on the camshaft side. The pump is driven from the motor through a round belt.

Guards and shields. All rotating pulleys are enclosed by guards which may be easily removed when required. The working zone of the automatic, flooded with cutting fluid during operation, is enclosed by hinged shields of transparent organic glass.

The electrical circuit is shown in the diagram (Fig. 106). Here remote motor control with a magnetic starter has been applied.

The circuit is connected to the power supply by the main line rotary switch.

Fuses protect the system against short circuits. The three-phase A. C. motor, type AO-41/4, used in the drive, has a power of 1.7 kw and a speed n_m=1,420 rpm.

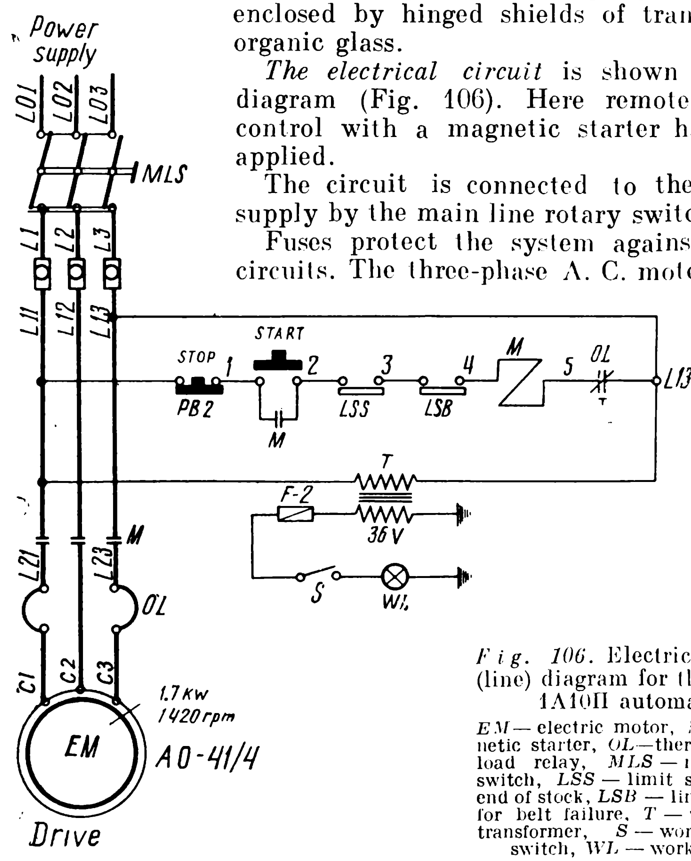


Fig. 106. Electric circuit (line) diagram for the model 1A10П automatic

EM — electric motor, *M* — magnetic starter, *OL*—thermal overload relay, *MLS* — main line switch, *LSS* — limit switch for end of stock, *LSB* — limit switch for belt failure, *T* — work light transformer, *S* — work light switch, *WL* — work light.

The motor is protected against prolonged overloads by the thermal relay *OL*.

The control circuit, which contains the coil of the magnetic starter *M*, comprises the normally closed contact of the "Stop" push-button, the normally open contact of the "Start" push-button and the normally closed contacts of the limit switches *LSS* and *LSB*.

Upon pressing the "Start" push-button, the magnetic starter coil is energised and the starter is closed. This closes the contacts for switching on the motor, as well as the auxiliary contact *M* of the holding circuit. The latter bypasses the normally open contact of the "Start" push-button.

Limit switches *LSS* and *LSB* shut down the automatic when they are tripped; the first operates when the bar stock is used up and the second when the drive belt breaks.

The work light *WL* is supplied from a low voltage circuit (36 V) by a step-down transformer *T*.

The work light circuit contains a single-pole fuse *F-2* and a tumbler switch *S*. The wiring on the automatic is enclosed in flexible metal conduit.

§ 76. SWISS-TYPE AUTOMATIC SCREW MACHINE, MODEL 1П12

The arrangement of the units and the gear trains of models 1П12 and 1А10П are the same.

The base and drive of model 1П12 differ from those on model 1А10П by their increased rigidity and higher available power. Besides this, the camshaft of model 1П12 has a high rotation speed for all idle motions, i. e., the camshaft is driven through two gear trains. One train is for working rotation and working feed while the second is for the idle (handling) motions.

The high speed friction clutch for camshaft rotation is automatically engaged and disengaged by the cams of a drum mounted on the camshaft.

The chucking mechanism of model 1П12 is the same as those usually employed on automatic screw machines of the turret type (models 1А124, 1А136, etc.).

In principle of operation and design, the tool frame assembly and rocker arm of model 1П12 resemble those of model 1А10П but are heavier and much more rigid, providing for high machining accuracy.

The following attachments are employed on Swiss-type automatic screw machines: 1) single-, two- and three-spindle drilling attachments, 2) single- and two-spindle threading attachments, 3) screw slotting attachment, and 4) precision turning attachment.

Installed attachments in no way hinder the operation of the principal units and mechanisms.

Drilling and threading spindles are more universal in application. They are included as standard accessories and furnished with each machine. The other attachments are designed for less frequently used operations and are available on special order only.

§ 77. SWISS-TYPE AUTOMATIC SCREW MACHINES, MODELS 110 AND 112

Automatics, models 110 and 112, are of identical design and differ only in their bar capacity (Table 15). As concerns their arrangement, principle of operation, and setting up methods, they resemble the above-described models 1A10П and 1П12 (see Fig. 16). Particulars in the design and kinematic arrangement differ to some extent.

The drive of these automatics is enclosed in the cabinet-type base which supports the bed. The upper part of the base is a pan for catching cutting fluid, chips, and finished parts. From the flange-mounted motor, rotation is transmitted through a V-belt drive to the intermediate shaft. An idler pulley is employed to tension the belt. Power is transmitted to a pump from the same motor, by a chain drive. From the intermediate shaft, rotation is transmitted through change gears to the countershaft. The spindle is driven by a flat belt from a long pulley on the countershaft. This belt is tensioned by a lever with an idler pulley. The lever is adjusted by a knob brought out on the front wall of the machine.

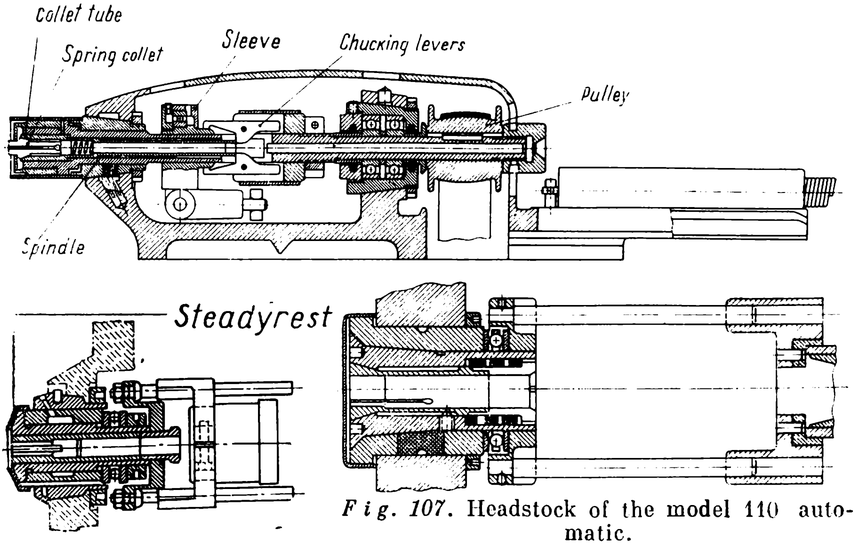


Fig. 107. Headstock of the model 110 automatic.

Pulleys for driving the camshaft and the slotting and threading attachments are also mounted on the countershaft.

The base is designed with an integral cutting fluid tank to which cutting fluid flows from a sump. A limit switch, mounted on the front inside wall, is a safety device and switches off the drive motor if the drive belt breaks. The motor is normally switched on and off from a push-button station.

These automatics have another limit switch which is tripped either by hand from a lever or automatically when the bar stock is used up or by the control mechanism of the threading or three-position attachments.

The bed which is mounted on the base has internal transverse ribbing and bosses for mounting the camshaft and auxiliary attachments.

The headstock (Fig. 107) is located at the right end of the bed. To change the endless belt without disassembling the countershaft (Fig. 108), one side of the belt is inserted into slot *4*, after removing screws *2*. Then ring *1* is turned, and, with it, bearing *3*.

The collet tube is pushed forward to close the collet by levers with long arms. This arrangement facilitates tube retraction to the initial position, when the collet is opened, with more reliability than in the construction employed in other automatics.

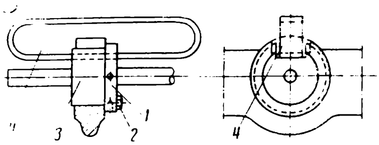


Fig. 108. Arrangement for changing belts on the drive shaft.

Longitudinal headstock feed is accomplished by the mechanism illustrated in Fig. 109. A single-edge cylinder cam *2* is mounted on the camshaft. It has a follower roller *3* on lever *4* which swivels on pivot *7*. Pivot *7* is held in bracket *6* fastened by screws to the end face of the bed. The pivot may be fitted into either of two holes (*I* and *II*) so that either a smaller or larger cam may be used. The toe *8* is secured in a slot in the left arm of lever *4*. The position of the toe in the slot is adjusted by the micrometric screw *9*. This varies the arm ratio of lever *4* and adjusts the length of headstock travel. Movement of lever *4* with the toe *8* actuates the slider *10* together with the headstock *1* to which it is fastened with screws *5*. The slider *10* may be adjusted along a longitudinal slot of the headstock to position the latter in reference to the steadyrest and toolslides.

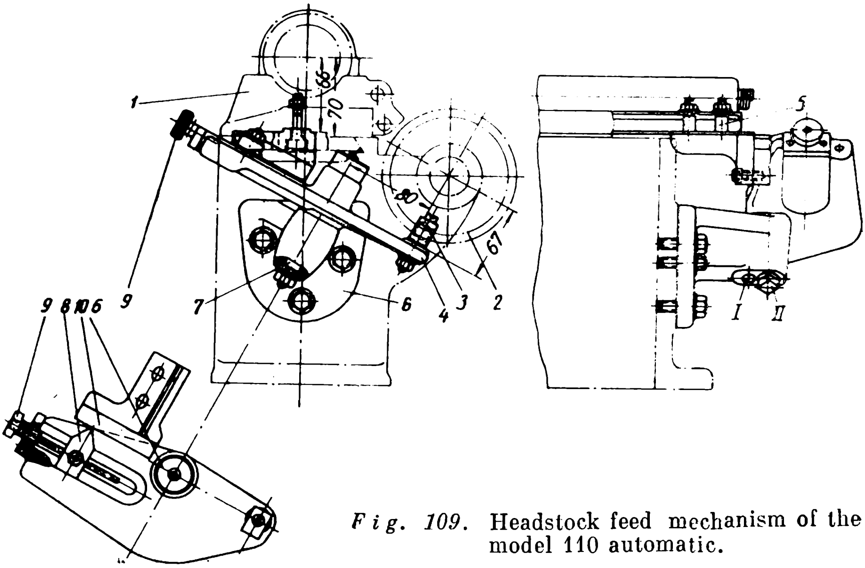


Fig. 109. Headstock feed mechanism of the model 110 automatic.

Steadyrests of various design may be installed on the model 110 automatic. They include the stationary type, rotary type with adjustable hole size, and rotary type with self-adjustment of hole size (see Fig. 107).

The reducing gear (Fig. 110) is driven from the countershaft pulley through pulley *5* on shaft *1*. From the latter, rotation is transmitted through two pairs of change gears, *16-15* and *14-11*, which enable the camshaft speed to be set up, and through the worm gearing to the camshaft *7*. The camshaft may also be rotated manually from handwheel *13*. For this purpose, shaft *12* is shifted until the gear of clutch *17* engages gear *9*, mounted freely on shaft *6*. The claw clutch will, at the same time, be disengaged from clutch *10* and will engage the clutch teeth of gear *9*.

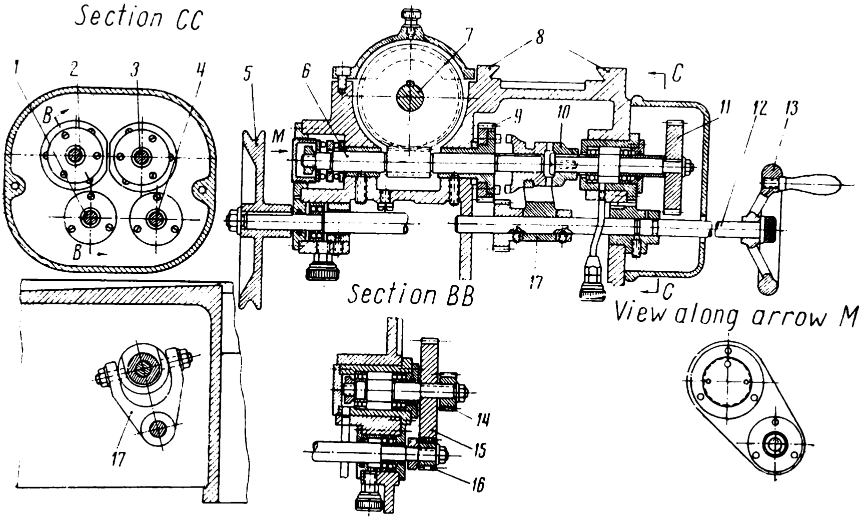


Fig. 110. Camshaft drive of the model 110 automatic.

1, *2*, and *3*—shafts of the drive, *4*—hand operation shaft, *5*—pulley, *6*—worm shaft, *7*—camshaft, *8*—ways for the headstock, *9*—hand operation gear, *10*—power drive clutch, *11*, *14*, *15* and *16* — change gears, *12* and *13*—shaft and handwheel for hand operation, *17*—double claw clutch with gear.

The camshaft is arranged behind the bed. Either a plate or cylinder cam may be used for headstock feed (see Fig. 109); other units are controlled by plate cams.

Toolslides. Models 110 and 112 have a rocker arm (see Fig. 37 *a*) and two overhead toolslides (see Fig. 37 *b*). The horizontal slides are located on a single rocker arm as in models 1A10П and 1П12 (described above). The rocker arm is operated from a plate cam on the camshaft.

In the front rocker arm slide the tool is set right side up; the tool is inverted in the rear slide. The tools are set to the work axis by swivelling the overhead toolholders about a horizontal pivot. After this, the toolholders are clamped by the front and rear screws. Micrometric screws are provided for precise settings in the radial and axial directions. The two overhead slides may operate independently of each other. After setting the overhead slides in reference to the workpiece, they are tightly clamped by screws.

§ 78. SINGLE-SPINDLE DRILLING ATTACHMENT

The single-spindle drilling attachment (Fig. 111) used on the automatics, models 1A10П and 1П12, has a drilling capacity of 3 mm in steel and 4 mm in brass. The maximum drilling depth is 30 mm. The

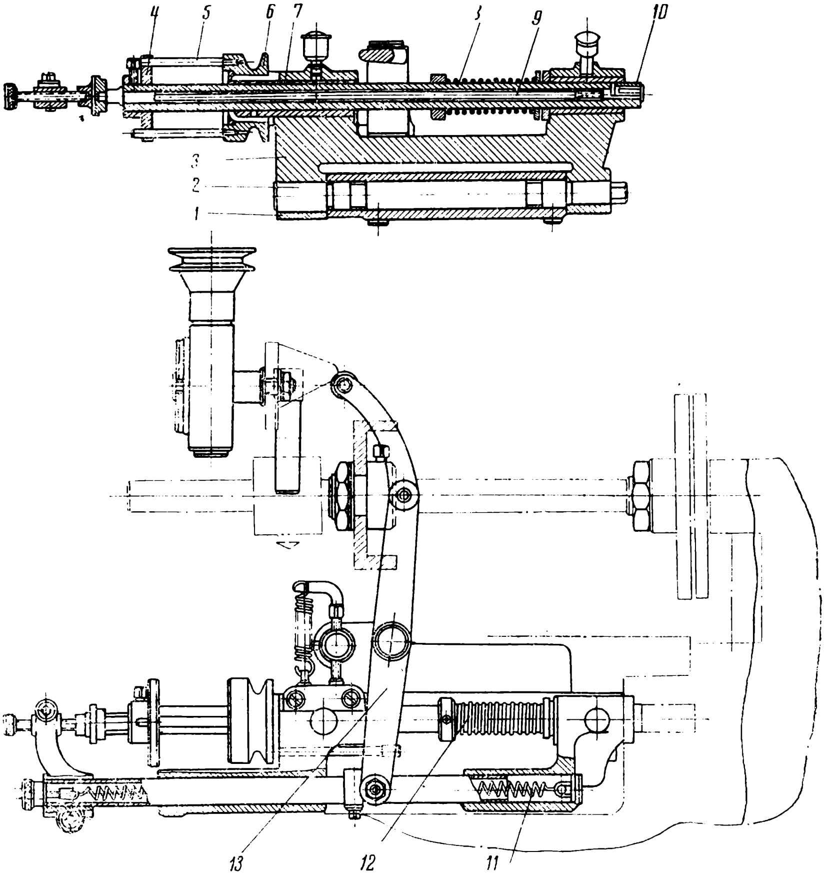


Fig. 111. Single-spindle drilling attachment for automatics, models 1A10П and 1П12.

maximum spindle speed is 9,375 rpm. In construction, this attachment consists of the body *3*, mounted on the eccentric pivot *2* of bracket *1* and carrying the drilling spindle *9*, sleeve *8* and the spindle feed mechanism.

The eccentric pivot enables the drilling spindle to be aligned with the work axis. A collet *10* for clamping the drill is arranged at the front end of the spindle.

The drilling spindle is rotated from pulley *6* through two drivers *5* and disc *4*. The pulley runs freely on needle rollers on bushing *7*. This relieves the spindle of the belt tension load.

Longitudinal feed of the spindle is obtained through the coil spring *11*. The spindle is withdrawn by coil spring *12* mounted directly on the spindle.

In drilling deep holes of small diameter, the drill is repeatedly withdrawn from the hole. A special attachment *13* may be installed in a bore of the front bracket of the bed to provide for multiple withdrawal of the drill.

§ 79. TWO-SPINDLE SWINGING DRILLING ATTACHMENT

The two-spindle swinging drilling attachment used on automatics, models 1A10П and 1П12, is designed for spotting, drilling and enlarging holes, as well as for drilling deep holes of small diameter.

The base of this attachment is mounted on a horizontal surface of the bed. It is located by two keys in a keyway and is fastened by two screws.

The drilling spindle is driven from the transmission shaft (see Fig. 102).

In operation of the right-hand drill, the spindle is driven by a large pulley; for the left-hand drill, the spindle is driven through a crossed belt from the small pulley (for medium diameters of drills or from the large pulley (for small size drills).

This drilling attachment provides for drilling holes in steel from 0.4 to 3 mm in diameter and from 0.4 to 4 mm in brass. The drilling depth is 30 mm.

The body *16* is mounted on the eccentric pivot *17* in the base. Body *16* carries the stationary spotting spindle. The body of the rotary drilling spindle (Fig. 112) is mounted on another eccentric pivot.

Plate cam *10*, on the camshaft, has two lobes of different radius connected together with transition curves. Upon rotation of the camshaft, this cam swings the body of the spotting spindle, through lever *13*, until the spotting and work spindle axes coincide.

When roller *2* of lever *1* drops to the lesser radius lobe of plate cam *10*, tension spring *9* swings both spindle bodies to the adjustable stop screw. In this position, the axes of the drilling spindle and work coincide.

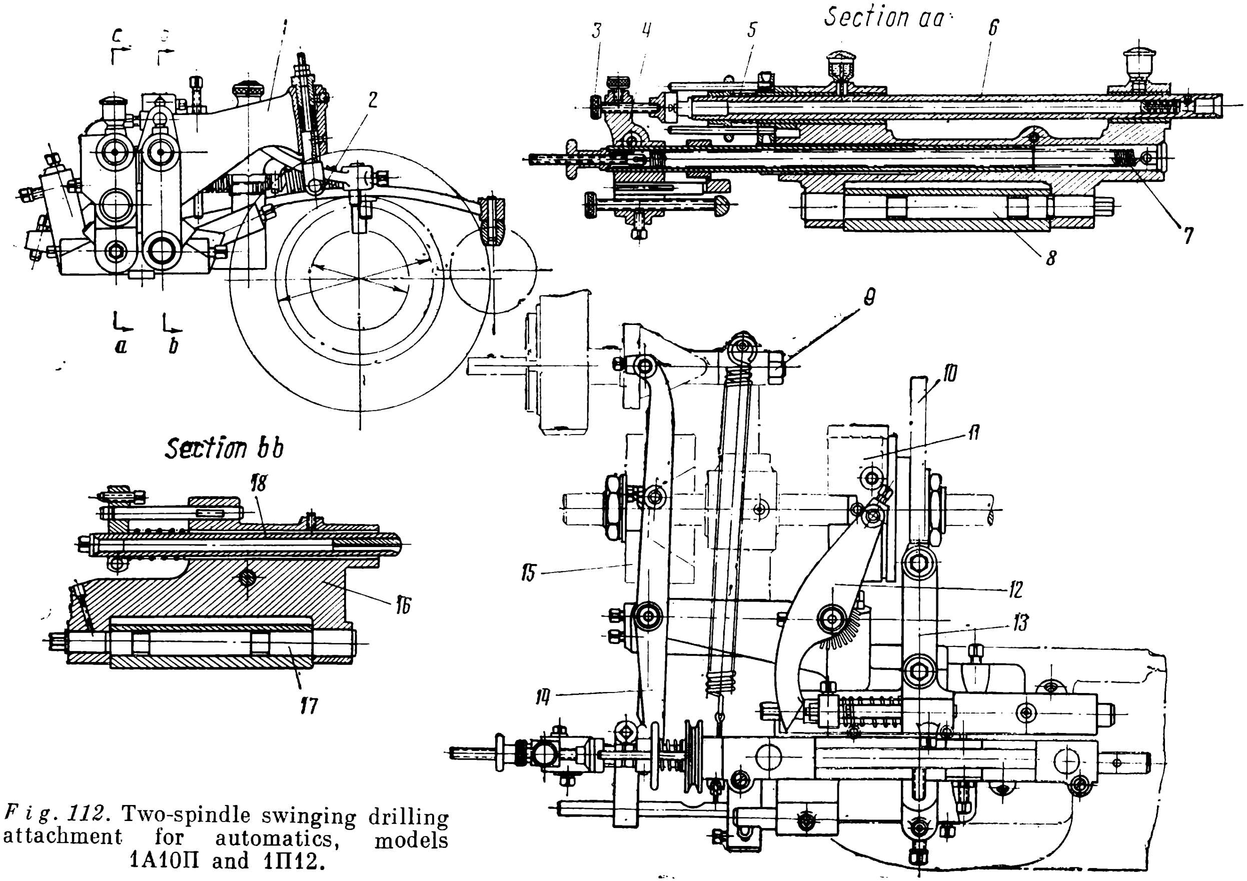


Fig. 112. Two-spindle swinging drilling attachment for automatics, models 1A10П and 1П12.

Axial feed of the spotting spindle *18* is obtained by the rocking lever *12* which is controlled by the cylinder cam *11* on the camshaft. The rate of feed depends on the cam. The spotting spindle is retracted by spring action.

Drilling spindle feed is obtained by means of a tension spring *7*, lever *4* and screw *3*. In operation, lever *14*, rocking on its pivot, is gradually retracted by cam *15* and thus provides for uniform feed of the spindle with the drill to the full drilling depth.

The drill is withdrawn by spring *5*, mounted directly on spindle *6*.

Interchangeable spring collets for holding drills are inserted in the bore at the spindle nose and are closed by a draw-bolt.

The position of the attachment is adjusted in a vertical plane by the eccentric pivots *8* and *17* in the spindle bodies and in a horizontal plane by a stop screw and spring *9*.

The attachment is lubricated by two wick-feed oilers, which must be replenished from time to time, and ball-type oilers.

The automatic may also accommodate a different type of two-spindle drilling attachment in which the spindles are shifted to the working position, not by swinging as in the above-described attachment, but by slide movement in a horizontal plane.

§ 80. THREE-SPINDLE DRILLING AND THREADING ATTACHMENT

This attachment for automatics, models 1A10П and 1П12, is also installed on a special pad on the bed and is located from a keyway.

The device consists of a base with an eccentric pivot that mounts a body having three spindles running in plain bearings. A lever for shifting the body to either of the three working positions and another lever for spindle travel are mounted on the base of the attachment. A drive shaft, arranged in the left-hand part of the body, carries two pulleys running on ball bearings. A tie-rod, running through the drive shaft, is linked by a dowel pin to a friction disc. The tapered surfaces of the disc may engage the internal tapers of the pulleys. Axial movement of the friction disc is accomplished by levers through a ring. The body with the spindles is shifted back by spring action.

Rotation is transmitted from the main transmission shaft throug a belt drive to the driving shaft pulleys of the attachment. Rotation is transmitted further through the friction disc to the three spindles. Two spindles rotate in the same direction as the work spindle while the third spindle rotates in the opposite direction.

Longitudinal feed of the spindle that occupies the working position is obtained from a cam, mounted on a drum of the camshaft, through a lever and a push rod with a collar.

The spindle is withdrawn to its initial position by coil springs located in the body.

The attachment body is shifted to change spindles by plate cams of the camshaft through a lever. The lever carries a follower pin on one end and a roller on the other. The roller bears against a strip on the body.

The friction disc is shifted to engage one of the two pulleys by a lever system controlled from cams on a camshaft drum.

§ 81. SINGLE-SPINDLE THREADING ATTACHMENT

The single-spindle threading attachment for the automatics, models 1А10П and 1П12 (Fig. 113) is designed to cut thread on a length of 40 mm (of a size up to 1 mm in steel and up to 4 mm in brass). The range of threading spindle speeds is from 1,700 to 10,300 rpm.

In the operation of this attachment, lever *8* is actuated by the cam on drum *9* of the camshaft. This lever provides longitudinal feed of the threading spindle *15*. When the die, clamped in the die-holder *16*, starts to cut ("runs on") the thread, lever *8* stops feeding the spindle and is returned by spring *10* to its initial position. Further axial movement of the spindle will be due to the lead of the die which will follow the thread. The action of lever *8* is cut short and only starts the thread.

Disc *11*, which travels together with spindle *15* to the right, reaches the head of adjusting screw *1* at the end of the thread. Screw *1* is held in lever *2* which carries blade *3* on its right-hand end. Disc *11* shifts lever *2* to the right and releases blade *4* of lever *5*, rocking on a pivot.

Under the action of coil spring *6*, a system of levers and a fork shift both belts from the right-hand pulley *14* to the left-hand idling pulley *12* and the central working pulley *13*. This provides for slow threading-spindle rotation (2.2 times slower than the work spindle). This speed is required to back the die off the work and to return the spindle to its initial position, due to the action of spring *7*.

The belt is shifted to its right-hand position to prepare the attachment for the next workpiece. This shift is accomplished by a special lever mounted on the camshaft.

The threading device has facilities for precisely setting the cutting tool, as well as a safety device which stops the automatic in case of overloads or if something goes wrong.

Swiss-type automatics allow the threading device to be employed in conjunction with another spindle which enables a hole to be drilled and thread cut on one workpiece.

§ 82. SCREW SLOTTING ATTACHMENT

The screw slotting attachment enables slots and flats to be milled on the cut-off end and burrs to be removed after cutting off. This excludes the need of an additional operation in many cases.

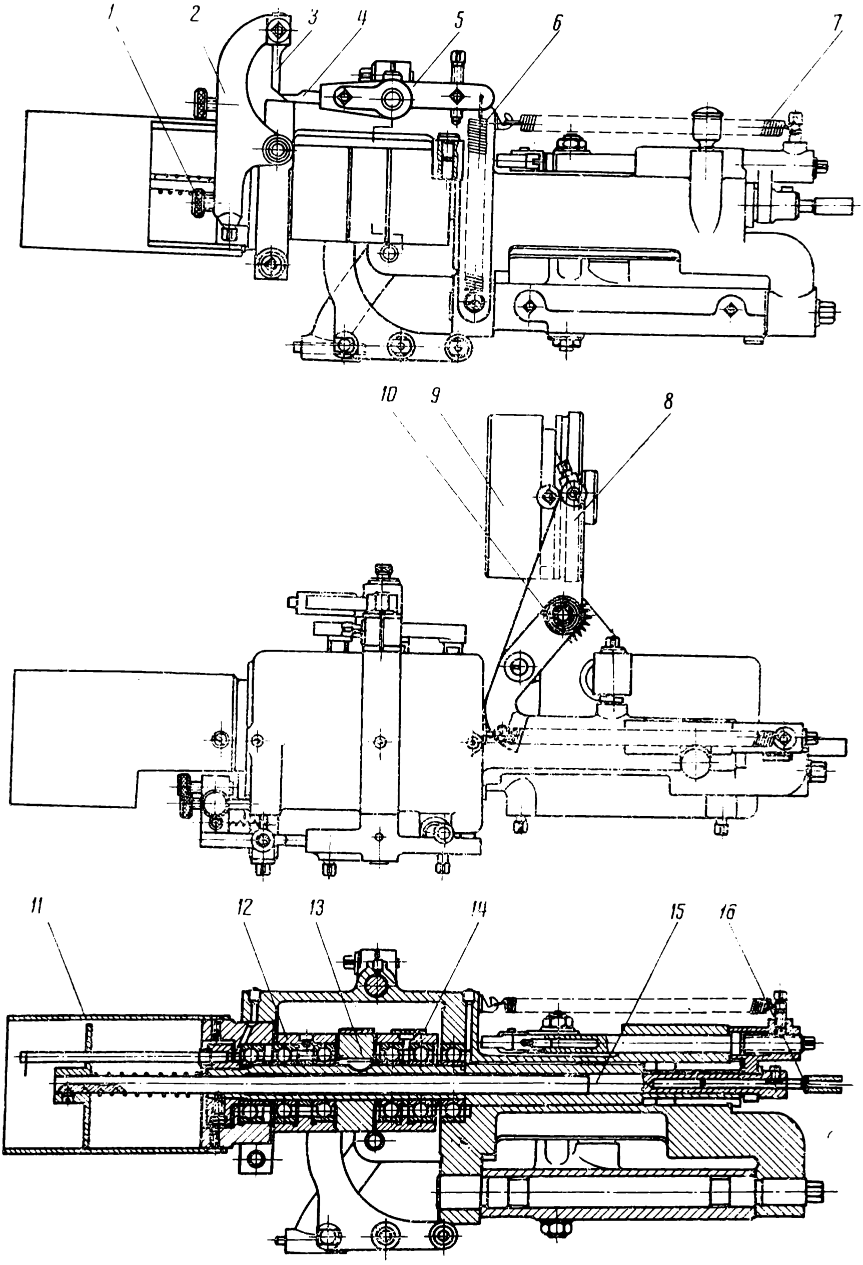


Fig. 113. Single-spindle threading attachment for automatics, models 1A10П and 1П12.

The slotting attachment may also be used as a catcher for separating small workpieces from the chips.

The slotting attachment is mounted on a special pad behind the bed, adjacent to the pad for mounting other attachments (drilling, threading, etc.)

The slotting attachment may operate together with other attachments.

The attachment spindle is driven by a belt from the transmission shaft.

One or two milling cutters, 25 mm in diameter, are mounted at the end of the spindle. They operate at speeds from 600 to 3,740 rpm. The depth of cut in the slot should not exceed 1.5 mm.

As the finished piece is severed from the bar, it is gripped by a clamping bushing of the arm and is carried to the cutter (or cutters) by the action of a section on a plate cam.

Axial movement of the grip arm and feed in milling is actuated by levers controlled by a face-type cylinder cam.

After the slot has been cut, the workpiece is ejected into a chute by a stop.

§ 83. SETTING UP SWISS-TYPE AUTOMATIC SCREW MACHINES

In selecting the manufacturing process and establishing the machining sequence, the more accurate surfaces should always be machined, whenever possible, by the rocker arm tools. The front tool (No. 1) is more suitable for this purpose as it operates to a positive stop. The rear tool (No. 2) is recommended for turning form surfaces with cross feed. External stepped surfaces may best be turned by the overhead tools, each of which is controlled by its own cam. The work is usually cut off with tool No. 3. *In planning the operation chart and laying out the cams, the moment that the bar is released is taken as the beginning of the cycle.* Settings and adjustments of the tools and longitudinal travel of the headstock are based on the position of the cut-off tool along the work axis. At the moment the bar is cut off, it usually projects 2 mm from the steadyrest bushing.

All calculations are made as indicated in Chapter II of Part Two.

The general approximate cycle time t_{app} is determined from the formula:

$$t_{app} = 1.5t_w = 90\frac{n_w}{n_s}\text{ sec.}$$

Setup data for laying out cams for the model 1A10П are calculated on the number of degrees (and not hundredths) required to perform each working and handling movement.

For rates of production up to 10 pieces per min, one degree of cam surface may be taken for each mm of rise and 0.5 degree for each mm of drop on the curves of the cam corresponding to idle movements

The magnitudes of lines of rise and drop on the cam should equal the actual movement required, multiplied by the transmission ratio from the cam to the toolslide.

Tooling Layout and Operation Sheet for the Model 1A10II Automatic and How It Is Drawn Up.

An example of the tooling layout and operation sheet employed for Swiss-type automatic screw machines is illustrated in Table 16.

In this example, a watchwork part, No. K 36-14, is to be turned of bar stock, $1.75_{-0.02}$ mm in diameter, of steel $\text{У}7_{AB}$ (U.S.S.R. Std. GOST 2589-44) to the third class of accuracy. The layout and operation sheet are designed in the following order:

1) The sequence of machining operations is established, cutting tools are selected, and their arrangement established.

2) The travel of all tools is determined, as well as feeds, required spindle revolutions for each operation element, lobes of the plate cams for one cycle, cutting speeds, etc.

3) Cam layouts are drawn and tools are designed on the basis of the calculated data.

All design data are set down in the operation or setup chart.

Cutting tool selection:

Tool No. 1 (straight turning tool) for turning diam 0.23 mm and chamfer 0.09×60° on diam 0.6 mm.

Tool No. 2 (second straight turning tool) for turning diam 0.78 mm, taper 0°25′, and diam 0.23 mm.

Tool No. 3 (grooving tool for undercutting) for turning the 60° groove on the face of diam 1.75.

Tool No. 4 for turning both 90° tapers and for cutting off the work.

Tool No. 5 for turning chamfer 0.09×45° and taper 0°25′.

Chamfer 0.09×60° on taper 0°25′ and taper 90° are turned by combined bar feed and tool travel.

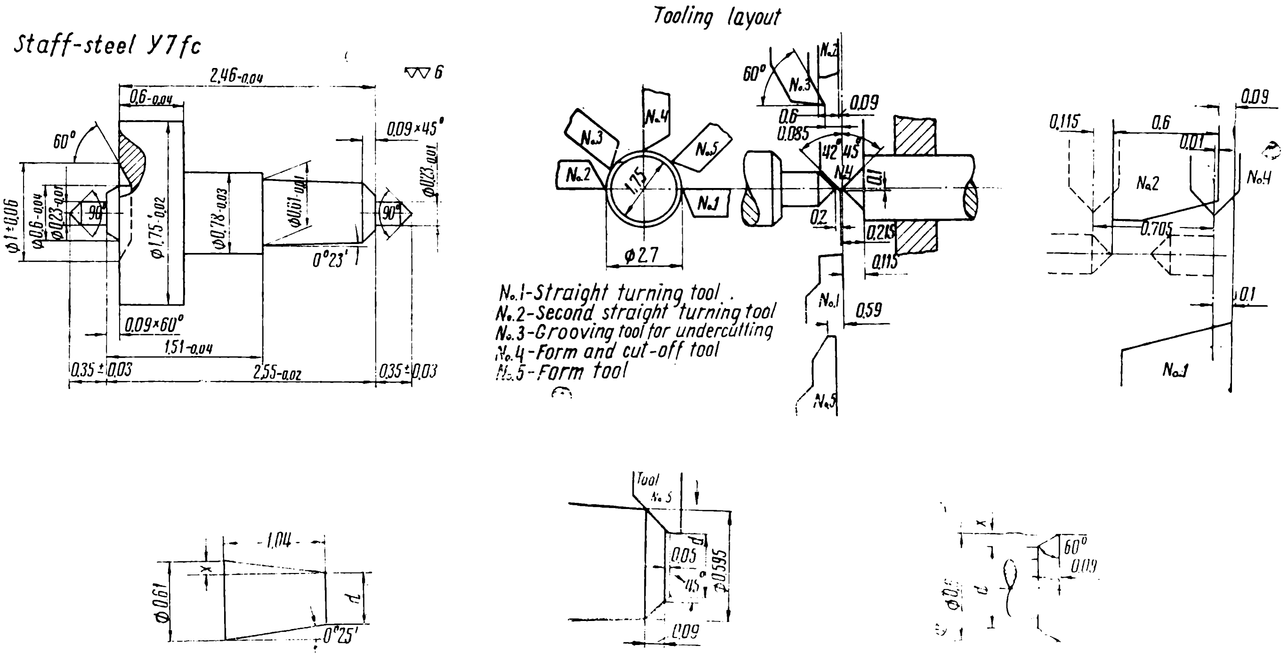
The tools are arranged in a position corresponding to diam 2.7 mm. This diameter, 2.7 mm, is the accepted diameter of the final position of the tools.

Determining the Travel of the Tools and Headstock

Operation element No. 1 —withdraw tool No. 4 to diam 2.7 mm. $l_1=\frac{2.7}{2}+0.1=1.45$ mm, in which 0.1 is the overrun of tool No. 4 beyond the bar centre.

Operation element No. 2 —advance tool No. 2 to diam 0.23 mm. $l_2=\frac{2.7-0.23}{2}=1.235$ mm (operation elements No. 1 and No. 2 overlap).

Operation element No. 3—turn diam 0.23 mm. $l_3=0.35$ mm.



Staff-steel У7fc

Tooling layout

N.1-Straight turning tool.
N.2-Second straight turning tool
N.3-Grooving tool for undercutting
N.4-Form and cut-off tool
N.5-Form tool

Refers to Table 16.

Table 16

Operation Sheet for Swiss-Type Precision Automatic Screw Machine, Model 1A10II

No.	Operation elements	Tool travel l, mm	Feed s, mm per rev.	Spindle revolutions required for each operation element		Degrees for each operation element				Lever arm ratio	Rise and drop on cam	Cam layout data				Cam name or number
						Working travel		Idle motions				Degrees		Lobe radii		
				Working travel	After deducting overlapped motions	Required	After deducting overlapped elements	Required	After deducting overlapped elements			from	to	from	to	
1	Withdraw tool No.4 to diam 2.7 mm	1.45	—	—	—	—	—	2	2	2:1	2.9	0	2	60	to template	No.4
2	Advance tool No.1 to diam 0.23 mm	1.235	—	—	—	—	—	(2)	—	3:1	3.705	0	(2)	56.295	52.59	RA*
3	Turn diam $0.23_{-0.01}$. 0.01. H** travel . .	0.35	0.003	117	117	16	16	—	—	3:1	1.05	2	18	68.18	69.23	H
4	Dwell	—	—	—	—	—	—	2	2	—	—	18	20	—	—	—
5	Withdraw tool No. 1 to diam 0.5 mm . . .	0.135	—	—	—	—	—	2	2	3:1	0.405	20	22	52.59	52.995	RA
6	Dwell	—	—	—	—	—	—	2	2			22	24	—	—	—
7	Chamfer. Tool No.1 fed to diam 0.6 mm	0.05	—	(90)	—	(12)	—	—	—	3:1	0.15	(24)	(36)	52.995	53.145	RA
8	Chamfer. H travel	0.09	0.001	90	90	12	12	—	—	3:1	0.27	24	36	69.23	69.5	H
9	Dwell	—	—	—	—	—	—	2	2	—	—	36	38	—	—	—

No.	Operation elements	Tool travel l, mm	Feed s, mm per rev	Spindle revolutions required for each operation element		Degrees for each operation element				Lever arm ratio	Rise and drop on cam	Cam layout data				Cam name or number
						Working travel		Idle motions				Degrees		Lobe radii		
				Working travel	After deducting overlapped motions	Required	After deducting overlapped elements	Required	After deducting overlapped elements			from	to	from	to	
10	Withdraw tool No. 1 to diam 2.7 mm	1.05	—	—	—	—	—	4	4	3:1	3.15	38	42	53.145	56.295	RA
11	Advance tool No. 3 to diam 0.6 mm	1.05	—	—	—	—	—	(3)		1:1	1.05	(39)	(42)	to template	60	No. 3
12	Dwell	—	—	—	—	—	—	2	2	—	—	42	44	—	—	—
13	Undercut chamfer. H. travel	0.2	0.0015	134	134	18	18	—	—	3:1	0.6	44	62	69.5	70.1	H
14	Dwell	—	—	—	—	—	—	2	2	—	—	62	64	—	—	—
15	Withdraw H	0.2	—	—	—	—	—	2	2	3:1	0.6	64	66	70.1	69.5	H
16	Withdraw tool No. 3 to diam 2.7 mm	1.05	—	—	—	—	—	2	2	1:1	1.05	66	68	60		No. 3
17	Feed bar for turning	1.29	—	—	—	—	—	5	5	3:1	3.87	68	73	69.5	73.37	H
18	Advance tool No. 2 to diam 1.8 mm	0.45	—	—	—	—	—	2	2	3:1	1.35	73	75	56.295	57.645	RA

No.	Operation elements	Tool travel l, mm	Feed s, mm per rev.	Spindle revolutions required for each operation element		Degrees for each operation element				Lever arm ratio	Rise and drop on cam	Cam layout data				Cam name or number
						Working travel		Idle motions				Degrees		Lobe radii		
				Working travel	After deducting overlapped motions	Required	After deducting overlapped elements	Required	After deducting overlapped elements			from	to	from	to	
19	Feed in tool No. 2 to diam 0.78 mm . . .	0.51	0.0015	340	340	46	46	—	—	3:1	1.53	75	121	57.645	59.175	RA
20	Dwell	—	—	—	—	—	—	2	2	—	—	121	123	—	—	—
21	Turn diam $0.78_{-0.13}$. H travel	0.82	0.004	205	205	26	26	—	—	3:1	2.46	123	149	73.37	75.83	H
22	Dwell	—	—	—	—	—	—	2	2	—	—	149	151	—	—	—
23	Feed in tool No. 2 to diam 0.61 mm . . .	0.083	0.001	85	85	11	11	—	—	3:1	0.255	151	162	59.175	59.43	RA
24	Dwell	—	—	—	—	—	—	2	2	—	—	162	164	—	—	—
25	Turn taper. Tool No. 2 travels to diam 0.53 . . .	0.008	—	(347)	—	(47)	—	—	—	3:1	0.024	(164)	(211)	59.43	59.454	RA
26	Turn taper. H travel	1.04	0.003	347	347	47	47	—	—	3:1	3.12	164	211	75.83	78.95	H
27	Dwell	—	—	—	—	—	—	2	2	—	—	211	213	—	—	—
28	Advance tool No. 5 to diam 0.6 mm	1.05	—	—	—	—	—	2	2	2:1	2.10	213	215	to template	59.714	No.5

Continued

No.	Operation elements	Tool travel *l*, mm	Feed *s*, mm per rev.	Spindle revolutions required for each operation element		Degrees for each operation element				Lever arm ratio	Rise and drop on cam	Cam layout data				Cam name or number
						Working travel		Idle motions				Degrees		Lobe radii		
				Working travel	After deducting overlapped motions	Required	After deducting overlapped elements	Required	After deducting overlapped elements			from	to	from	to	
29	Chamfer. Tool No. 5 fed to diam 0.315 mm	0.143	0.001	143	143	19	19	—	—	2:1	0.286	215	234	59.714	60	No. 5
30	Dwell	—	—	—	—	—	—	2	2	—	—	234	236	—	—	—
31	Withdraw tool No. 5 to diam 2.7 mm . . .	1.193	—	—	—	—	—	(3)		2:1	2.386	(236)	(239)	60	to template	No. 5
32	Feed in tool No. 2 to diam 0.23 mm . . .	0.182	0.001	182	182	24	24	—	—	3:1	0.546	236	260	59.454	60	RA
33	Dwell	—	—	—	—	—	—	2	2	—	—	260	262	—	—	—
34	Turn diam $0.23_{-0.01}$. H travel	0.35	0.002	175	175	23	23	—	—	3:1	1.05	262	285	78.95	80	H
35	Dwell	—	—	—	—	—	—	2	2	—	—	285	287	—	—	—
36	Withdraw tool No. 2 to diam 2.7 mm	1.235	—	—	—	—	—	3	3	3:1	3.705	287	290	60	56.295	No. 6

Continued

No.	Operation elements	Tool travel l, mm	Feed s, mm per rev.	Spindle revolutions required for each operation element		Degrees for each operation element				Lever arm ratio	Rise and drop on cam	Cam layout data				Cam name or number
						Working travel		Idle motions				Degrees		Lobe radii		
				Working travel	After deducting overlapped motions	Required	After deducting overlapped elements	Required	After deducting overlapped elements			from	to	from	to	
37	Withdraw bar for cut off. H travel	0.705	—	—	—	—	—	3	3	3:1	2.115	290	293	80	77.885	II
38	Advance tool No. 4 to diam 0.23 mm	1.235	—	—	—	—	—	3	3	2:1	2.47	293	296	57.1	59.57	No. 4
39	Cut off. Tool No. 4 travels beyond centre	0.215	0.001	(215)	—	(29)	—	—	—	2:1	0.43	(296)	(325)	59.57	60	No. 4
40	Cut off. II travel	0.215	0.001	215	—	29	29	—	—	3:1	0.645	296	325	77.885	78.53	H
41	Dwell	—	—	—	—	—	—	2	2	—	—	325	327	—	—	—
42	Chuck opens . .	—	—	—	—	—	—	10	10	—	—	327	337	—	—	—
43	Withdraw headstock	3.45	—	—	—	—	—	8	8	3:1	10.35	337	345	78.53	68.18	H
44	Chuck closes . .	—	—	—	—	—	—	15	15	—	—	345	360	—	—	—

Total . . . . . . $n_w = 2{,}033$; $K_w = 271°$, $K_i = 89°$; $n_{deg} = \frac{2{,}033}{271} \approx 7.5$ rev per degre e; $n_{cycle} = 2{,}700$ revolutions; $T_c =$ $= 36$ sec; $Q_g = 1.67$ pcs per min; $Q_a = 1.5$ pcs per min.

* RA—Rocker arm

** H — Headstock.

Operation element No. 5 —withdraw tool No. 1 to diam 0.5 mm (to the beginning of the chamfer $l_5 = \frac{0.5-0.23}{2} = 0.135$ mm), in which diam 0.5 mm is determined from the sketch:

$$X = \frac{0.09}{\cot 30^\circ} = \frac{0.09}{1.73} = 0.05$$

$$d = 0.6 - 2 \times 0.05 = 0.5.$$

Operation element No. 7—turn chamfer 0.09×60°. Tool No. 1 travels to diam 0.6 mm:

$$l_7 = \frac{0.6-0.5}{2} = 0.05 \text{ mm}.$$

Operation element No. 8—turn chamfer 0.09×60°. Headstock travel $l_8 = 0.09$ mm (operation elements No. 7 and No. 8 overlap).

Operation element No. 10—withdraw tool No. 1 to diam 2.7 mm.

$$l_{10} = \frac{2.7-0.6}{2} = 1.05 \text{ mm}.$$

Operation element No. 11— advance tool No. 3 to diam 0.6 mm.

$$l_{11} = \frac{2.7-0.6}{2} = 1.05 \text{ mm}.$$

Operation element No. 13—undercut chamfer. Headstock travel $l_{13} = 0.115 + 0.085 = 0.2$ mm, in which 0.115 mm is the groove depth and 0.085 mm is the clearance between tool No. 3 and the face of the shoulder diam 0.75 mm (see tooling arrangement in the setup chart).

Operation element No. 15—withdraw the headstock. $l_{15} = 0.2$ mm (required to withdraw tool No. 3).

Operation element No. 16—withdraw tool No. 3 to diam 2.7 mm.

$$l_{16} = \frac{2.7-0.6}{2} = 1.05 \text{ mm}.$$

Operation element No. 17—feed bar for turning diam 0.078 mm. Headstock travel $l_{17} = 0.6 + 0.6 + 0.09 = 1.29$ mm, in which 0.6 mm is the length along diam 1.75 mm, 0.6 is the length of the second straight turning tool No. 2, and 0.09 mm is the distance between tools No. 1 and No. 2.

Operation element No. 18—advance tool No. 2 to diam 1.8 mm.

$$l_{18} = \frac{2.7-1.8}{2} = 0.45 \text{ mm (to the moment of tool infeed).}$$

Operation element No. 19—feed in tool No. 2 to diam 0.78 mm.

$$l_{19} = \frac{1.8-0.78}{2} = 0.51 \text{ mm}.$$

Operation element No. 21—turn diam 0.78 mm. Headstock travel $l_{21} = 1.51 - 0.09 - 0.6 = 0.82$ mm.

Operation element No. 23—feed in tool No. 2 to diam 0.61 mm.

$$l_{23} = \frac{0.78-0.61}{2} = 0.085 \text{ mm}.$$

Operation element No. 25—turn the taper. Tool No. 2 travels to diam 0.595 mm. $l_{25}=\frac{0.61-0.595}{2}=0.008$ mm, in which the dimension 0.595 mm is determined from the sketch, i. e.,

$$\tan 0°25'=0.00727.$$
$$x=\tan 0°25'\times 1.04=0.00727\times 1.04=0.0075.$$
$$a=0.61-(2\times 0.0075)=0.595 \text{ mm}.$$

Operation element No. 26—turn the taper. Headstock travel $l_{26}=2.55-1.51=1.04$ mm.

Operation element No. 28—advance tool No. 5 to diam 0.6 mm. $l_{28}=\frac{2.7-0.6}{2}=1.05$ mm.

Operation element No. 29—turn chamfer 0.09×45°. Tool No. 5 travels to diam 0.315 mm. $l_{29}=\frac{0.6-0.315}{2}=0.143$ mm, in which diam 0.315 mm is determined from the sketch of the part ($d=0.595-2(0.09+0.05)=0.315$ mm).

Operation element No. 31 — withdraw tool No. 5 to diam 2.7 mm. $l_{31}=\frac{2.7-0.315}{2}=1.193$ mm.

Operation element No. 32—feed in tool No. 2 to diam 0.23 mm. $l_{32}=\frac{0.595-0.23}{2}=0.182$ mm.

Operation element No. 34—turn diam 0.23. Headstock travel $l_{34}=0.35$ mm.

Operation element No. 36—withdraw tool No. 2 to diam 2.7 mm. $l_{36}=\frac{2.7-0.23}{2}=1.235$ mm.

Operation element No. 37—to set the bar stock properly for turning the 90° taper, it should be withdrawn. For this purpose, headstock travel $l_{37}=0.6+0.115-0.01=0.705$ mm, in which 0.6 mm is the width of the second straight turning tool No. 2; 0.115 mm is the length of the 90° taper at diam 0.23 mm, and 0.01 mm$=0.1-0.09$ (offset of the nose on the cut-off form tool No. 4 in reference to the front cutting edge of tool No. 2) (see sketch and tool layout).

Operation element No. 38—advance tool No. 4 to diam 0.23 mm. $l_{38}=\frac{2.7-0.23}{2}=1.235$ mm.

Operation element No. 39—cut off the work and turn the tapers. Tool No. 4 travels beyond the centre. $l_{39}=\frac{0.23}{2}+0.1=0.215$ mm, in which 0.1 mm is the overrun of tool No. 4 beyond the bar centre.

Operation element No. 40—cut off the work and turn the tapers. Headstock travel $l_{40}=\frac{0.23}{2}+0.1=0.215$ mm (operation element No. 39 and No. 40 overlap).

Operation element No. 43—withdraw headstock over distance $l_{43}=0.35+0.09+0.2-0.2+1.29+0.82+1.04+0.35-0.705+0.215=$ $=3.45$ mm (the components of this equation are the travel values of the headstock in the operation elements No. 3, 8, 13, 15, 17, 21, 26, 34, 37 and 40). The withdrawal of the headstock at the cycle end is equal, as a rule, to the total length of the workpiece plus the width of the cut-off tool, i.e., $3.45=2.55+(0.35\times 2)+0.2$, in which $2.55+(0.35\times 2)=3.25$ mm which is the workpiece length on the sketch and 0.2 mm is the width of the cut off.

Feed selection. The rates of feed—0.003, 0.001, 0.0015, 0.004, and 0.002 mm per revolution have been selected on the basis of experience acquired in a watch factory manufacturing part No. K 36-14.

The number of spindle revolutions required for each operation element n_o is determined from the formula:

$$n_o=\frac{l}{s} \text{ revolutions}$$

in which l is the tool or headstock travel in mm,
s is the rate of feed in mm per revolution.

$n_3=\frac{0.35}{0.003}=117$ revolutions $n_{23}=\frac{0.085}{0.001}=85$ revolutions

$n_7=n_8=\frac{0.09}{0.001}=90$ revolutions $n_{25}=n_{26}=\frac{1.04}{0.003}=347$ revolutions

$n_{13}=\frac{0.25}{0.0015}=134$ revolutions $n_{29}=\frac{0.143}{0.001}=143$ revolutions

$n_{19}=\frac{0.51}{0.0015}=340$ revolutions $n_{32}=\frac{0.182}{0.001}=182$ revolutions

$n_{21}=\frac{0.82}{0.004}=205$ revolutions $n_{31}=\frac{0.35}{0.002}=175$ revolutions

$n_{39}=n_{40}=\frac{0.215}{0.001}=215$ revolutions.

Determining the sum of spindle revolutions n_w *required for all working movements after deducting overlapped movements and accepted for calculations*: $n_w=117+90+134+340+205+85+347+143+$ $+182+175+215=2{,}033$ revolutions. The following lever arm ratios have been set up: headstock—3 : 1, rocker arm—3 : 1, toolslide No. 3—1 : 1, and toolslides No. 4 and 5—2 : 1. The rises and drops on the cam are calculated on the basis of the established lever arm ratios.

The number of degrees required on the plate cam for auxiliary or idle motions is determined on the basis of 1° to 1½° for each millimetre of cam rise and from ½° to 1° for each millimetre of drop.

Rises on the cams are required for feeding out the stock, for the travel of tools No. 2, 3, 4, and 5 toward the work axis and for withdrawing tool No. 1 from the work.

Drops on the cams are required for withdrawing the headstock, withdrawing tools No. 2, 3, 4, and 5 from the work and for advancing tool No. 1 to the work.

Certain operation elements include dwells for more reliability in coordinating the movement of the units (operation elements No. 17 and No. 43). Each dwell corresponds to 2°. The angles required for auxiliary travel (idle movements) have been rounded off with a minimum value of 2°.

The sum of degrees required on the cams for idle movements, after deducting the overlapped movements and accepted for calculations, is determined from the following equation: $K_i=2+2+2+2+2+4+$ $+2+2+2+2+5+2+2+2+2+2+2+2+2+2+3+3+3+2+10+$ $8+15=89°$.

The sum of degrees required on the cams for working movements after deducting overlapped movements will be

$$K_w=360°-89°=271°.$$

The number of degrees required for each lobe on the plate cams for the working movements (columns 7 to 10, incl.) is determined from the formula:

$$n_{deg}=\frac{n_w}{K_w};\quad k_o=\frac{n_o}{n_{deg}}\ \text{(see also § 58)}.$$

$$k_o=\frac{K_w}{n_w}\times n_o,$$

in which n_o is the number of spindle revolutions for any working movement (columns 5 and 6).

$$k_{o_3}=\frac{271}{2,033}\times 117=16° \qquad k_{o_{23}}=\frac{271}{2,033}\times 85=11°$$

$$k_{o_7}=k_{o_8}=\frac{271}{2,033}\times 90=12° \qquad k_{o_{25}}=k_{o_{26}}=\frac{271}{2,033}\times 347=47°$$

$$k_{o_{13}}=\frac{271}{2,033}\times 134=18° \qquad k_{o_{29}}=\frac{271}{2,033}\times 143=19°$$

$$k_{o_{19}}=\frac{271}{2,033}\times 340=46° \qquad k_{o_{32}}=\frac{271}{2,033}\times 182=24°$$

$$k_{o_{21}}=\frac{271}{2,033}\times 205=26° \qquad k_{o_{34}}=\frac{271}{2,033}\times 175=23°$$

$$k_{o_{39}}=k_{o_{40}}=\frac{271}{2,033}\times 215=29°.$$

The angles of the operation elements are put down in the setup chart in an increasing order (columns 13 and 14).

Determining the lobe radii on the cams. To determine the lobe radii, select the operation element with the maximum radius.

In our example, the maximum cam lobe radius of the headstock cam ($R=80$ mm) corresponds to operation No. 34 having maximum forward travel. The maximum radius ($R=60$ mm) of the rocker arm cam corresponds to operation element No. 32 in which tool No. 2 is fed in to diameter 0.23 mm. Maximum lobe radii of the overhead slide cams ($R=60$ mm) correspond to operation element No. 13 for tool No. 3, operation element No. 39 (at the end of cut-off) for tool No. 4, and operation element No. 29 for tool No. 5.

The radii of the other lobes on the cams are to be determined as indicated in § 59. The calculated values are set down in columns 15 and 16; the designations of the cams are given in column 17.

The number of spindle revolutions required to make one piece, is determined from the formula:

$$n_{cycle}=\frac{n_w\times 360^\circ}{K_w}=\frac{2,033\times 360^\circ}{271^\circ}=2,700 \text{ revolutions.}$$

The cutting speed v is determined from plant data. For steel $У7_{AB}$ (free-cutting), the cutting speed $v=30$ m per min.

The spindle speed, corresponding to this cutting speed, is determined as follows:

$$n_s=\frac{1,000v}{\pi d}=\frac{1,000\times 30}{3.14\times 1.75}=5,450 \text{ rpm.}$$

The nearest lower speed available on the machine (as indicated in the Service Manual) $n_s=5,000$ rpm. Thus the actual cutting speed $v=27.5$ m per min.

The cycle time (time to make one piece) is calculated from the formula:

$$T'_c=\frac{n_{cycle}}{n_s}=\frac{2,700}{5,000}\times 60=32 \text{ sec.}$$

We select the nearest larger cycle time from the Service Manual ($T_c=36$ sec).

Determining the rate of production:

$$Q_g=\frac{60}{T_c}=\frac{60}{36}=1.67 \text{ pcs per min.}$$

This rate of production and the spindle speed $n_s=5,000$ rpm correspond to the change gears 35 and 90 teeth, pulley steps F—J and K—O, change pulley A=170 mm, and B=100 mm. The actual rate of production will be:

$$Q_a=Q_g\eta=1.67\times 0.9=1.5 \text{ pcs per min.}$$

Cams and tools are designed on the basis of the setup chart data.

§ 84. SWISS-TYPE AUTOMATIC SCREW MACHINE, MODEL 1125

The Swiss-type automatic, model 1125, which differs in design to a considerable extent from that of model 1A10П, has a bar capacity of 18 mm and a turning length of 150 mm. It has four cross-arranged toolslides and a four-station turret (Fig. 114). The work and tool spindles have infinitely variable speeds obtained electrically.

The headstock is fixed (Fig. 115 *a*) in this machine but the rotating spindle and feeding tube have an axial movement that provides for longitudinal feed in addition to the rotary cutting motion.

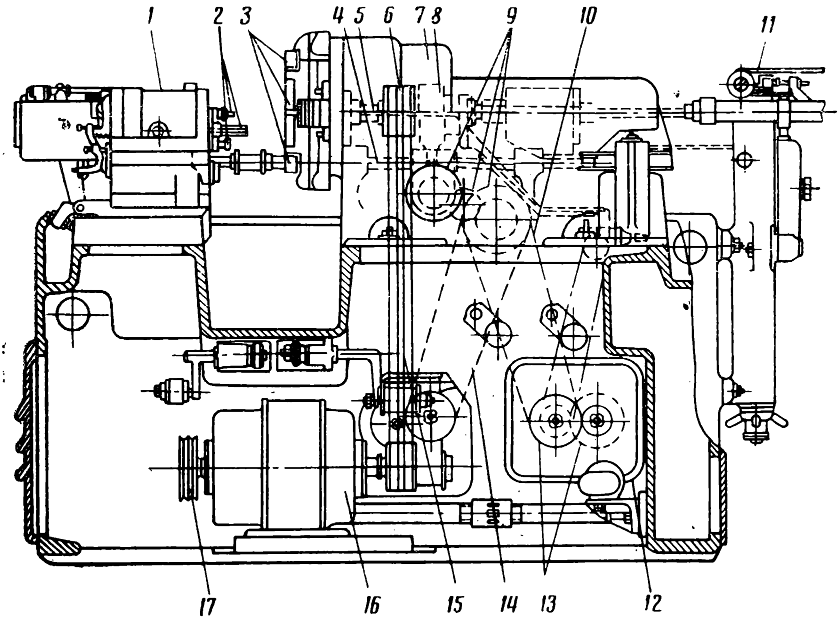


Fig. 114. Swiss-type automatic screw machine, model 1125.

1—four-station turret with rotary tool spindles *2*, *3*—four-slide cross-arranged tool frame with cross-feeding tools, *4*—camshaft, *5*—work spindle, *6* and *15*—pulleys of belt drive from the motor *16*, *7*—headstock, *8*—worm gearing in the camshaft drive, powered by motor *16* through chain gearing *14*, ordinary gearing and change gears *9*, *12*—motor for high-speed camshaft rotation through spur gears *13*, chain drive *10*, gear *9* and worm gearing *8*, *11*—bar feed mechanism, *17*—V-belt pulleys for driving tool spindles *2* of the turret

A steadyrest collet (Fig. 115 *b*) is arranged at the front end of the spindle. The spindle contains two tubes which also rotate. One provides for longitudinal feed and the other, outer tube, for closing the collet. The tool slide assembly (Figs. 116 and 117) comprises four bases secured to the tool frame of the stationary headstock. An intermediate member, which carries the upper slide and the toolholder, travels in each toolslide base. Each toolslide is actuated by a cam surface mounted on a lever. The latter are controlled by cams on the camshaft.

The toolslides are provided with positive stops used in precise turning operations.

The turret (Fig. 114, *1*) has four stations for mounting tool spindles which may be rotated through V-belts. The turret is locked after each indexing.

The camshaft (Fig. 114, *4*) may rotate at a constant speed during the full cycle. Camshaft speed is set up by the D. C. drive motor *16*. The camshaft is driven through the chain drive *14*, change gears *9*, and worm gearing *8*.

In manufacturing complex work with a cycle time T_c exceeding 20 or 25 sec, the camshaft may be imparted a second high-speed rotation for performing auxiliary or idle operations. For this purpose, the camshaft is driven from motor *12* through spur, chain and worm gearing *13*, *10*, *9*, and *8*.

Setting Up. Spindle speeds are set up in an infinitely variable range by an electrical arrangement.

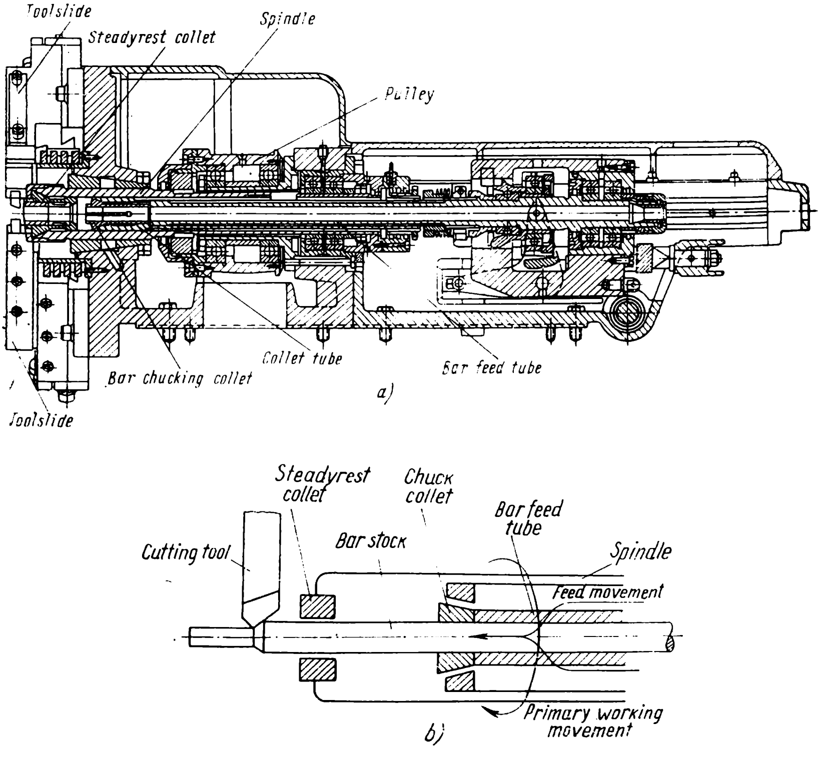


Fig. 115. Longitudinal section through the headstock of the model 1125 automatic.

Work spindle speeds are determined by the formula:

$$n_s = n_m \frac{142}{112} \text{ rpm},$$

while the tool spindle speed is calculated from:

$$n_{ts} = n_m \frac{100}{94} \times \frac{75}{54} \text{ rpm},$$

in which n_m is the speed of electric motor *16* (Fig. 114).

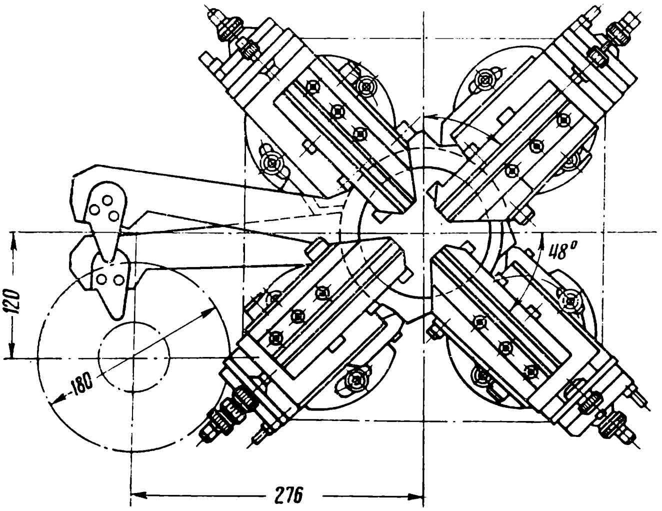


Fig. 116. Toolslides of the model 1125 automatic.

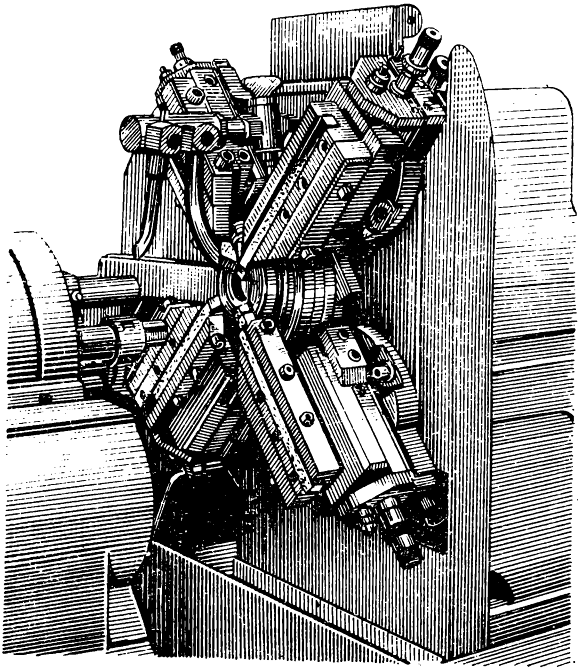


Fig. 117. General view of the tool frame on the model 1125 automatic.

The camshaft speed (n_{cs}) is determined from the formula:

$$n_{cs}=n_m\times 0.00085\,\frac{a}{b}\times\frac{c}{d}\ \text{rpm}.$$

The cycle time for setups with constant camshaft speed is calculated from the formula:

$$T_c=\frac{1}{n_{cs}}\,\text{min}.$$

The camshaft speed at high-speed rotation will be:

$$n_{cs}^{hs}=n'_m\frac{20}{114}\times\frac{29}{35}\times\frac{1}{50}=n'_m\times 0.0029\ \text{rpm}.$$

Cycle time for setups with high speed camshaft rotation (for idle motions) will be:

$$T'_c=\left(\frac{1}{n_{cs}}\times\frac{\alpha_w}{360}+\frac{1}{n_{cs}^{hs}}\times\frac{\alpha_i}{360}\right)\ \text{min}$$

in which

α_w is the angle of camshaft rotation for working movements;

α_i is the angle of high-speed camshaft rotation ($\alpha_i=360-\alpha_w$).

CHAPTER II

AUTOMATIC SCREW MACHINES

§ 85. MACHINING SEQUENCE

Automatic screw machines are widely used units of production equipment. *Various models of automatic screw machines are almost identical in design and are set up and operated in the same manner.* These automatics produce complex work of bar stock. The provision of a magazine feed device enables separate blanks to be employed as well. Typical work machined on automatic screw machines is shown in Fig. 118.

The following operations are performed on automatic screw machines: *turning cylindrical, tapered and form surfaces, spotting, drilling, reaming, boring, cutting internal and external threads, knurling, and screw slotting.*

After the bar stock has been loaded into the machine, it is

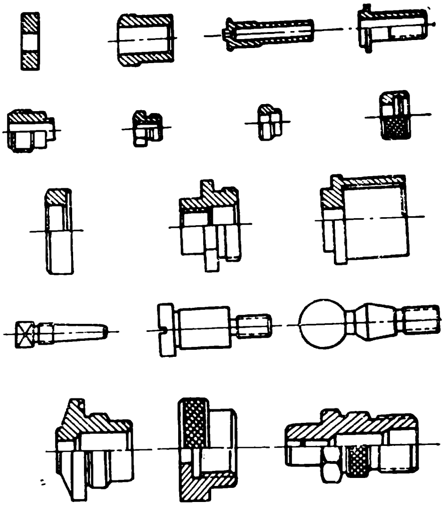


Fig. 118. Typical work machined on automatic screw machines.

automatically fed forward the required length to the stock stop which is set up in one of the tool holes of the turret. Internal and external surfaces are consecutively machined by tools mounted in the turret tool holes. The turret is indexed from position to position and has a longitudinal feed movement at each position. Cross fed tools are held in the cross slides. These tools are used for turning form surfaces, grooves, complex slots, face surfaces, knurling, and cutting off.

The operation of the cross slides and turret may be overlapped to a certain extent.

External surfaces may be turned by longitudinal feed of tools mounted in the turret or by cross feed of tools in the cross slides. It is advisable to take the heaviest cuts with the front cross slide.

Heavy chips may be cut with longitudinal feed by tangential tools if a very high class of surface finish is not required.

Internal surfaces are machined by ordinary cutting tools mounted in the turret.

A two-tool holder can be effectively employed for turning stepped workpieces. A box tool with a roller back rest is used in turning long accurate cylindrical surfaces. Toolholders with a single tool and without a back rest are used only for inaccurate surfaces or for turning with a fine chip.

Table 17

Brief Specifications of Automatic Screw Machines

Item	Unit	Model			
		1A113	1A118	1A124	1A136
1. Bar capacity	mm	12	18	25	36
2. Maximum stock feed .	mm	60	60	90	90
3. Maximum length turned	mm	50	50	80	80
4. Maximum thread cut in steel	mm	8	12	18	24
5. Cycle time range (time to make one piece) . . .	sec	2 to 200	3 to 180	8.1 to 477	11.6 to 467
6. Number of spindle speeds		18	16	Infinitely variable	Infinitely variable
7. Range of spindle speeds	rpm	56 to 5,038	133 to 3,360	110 to 2,800	100 to 2,000
8. Main drive motor power	kw	1.7 or 2.8	2.8	4.2	4.2
9. Overall dimensions: floor space occupied . .	mm	1,460× ×590	1,540× ×625	2,000× ×800	2,000×800
height	mm	1,335	1,330	1,500	1,500
10. Approximate net weight	kg	1,000	1,000	2,000	2,000

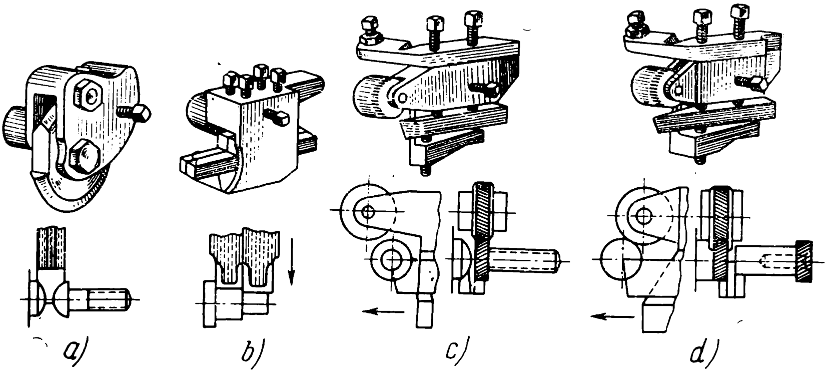


Fig. 119. Machining with cross slide tools.
a—forming and cutting off, *b*—turning two steps, *c* and *d*—knurling.

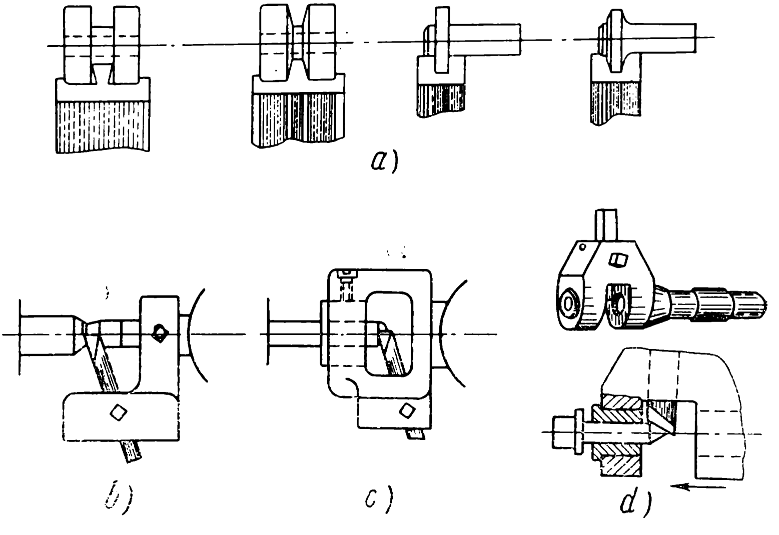


Fig. 120. Turning shoulders, chamfering, and pointing.

Small tapers of considerable length are turned by turret tools having supplementary cross feed controlled by a cam or template.

It is expedient to combine hole machining with external turning. Operations which may be performed with the same work speed and tool feed should be combined.

External surfaces may be turned with cross feed of tools held in the cross slides (Fig. 119). Form and wide-nose tools are efficient for: 1) complex forms, 2) maintaining precise axial dimensions, 3) surfaces of small length, and 4) surfaces located near to the chuck.

Grooves and shoulders are turned by cross-feeding tools (Fig. 120 *a*).

Machining performed with the cross slides may be partly or fully overlapped with operations of the turret tools. If cut off is partly overlapped with other operations, care must be taken that the remaining cross-section at the cut off is sufficient to perform the other operations, i. e., so that the reduction in rigidity does not impair the surface finish on the work.

Chamfers and radii are best turned on the projecting end of the work when the preceding piece is being cut off, since this reduces the overhang. In cases when some reason makes this impossible, chamfering should be combined with spotting (Fig. 120 *b*).

Chamfers should be turned on long work of small diameter with a toolholder having a guide bushing (Fig. 120 *c*).

Reverse centres are usually turned with a turret tool (Fig. 120 *d*).

Internal surfaces are machined in much the same manner as with a turret lathe. It is advisable to spot holes before drilling (Fig. 121). If the work has a through hole, it may be spotted by increasing the drill travel of the preceding workpiece but this may involve runout of the spotted hole. Core drilling and reaming are performed at lower cutting speeds than drilling and turning and, therefore, they require a change in spindle speed.

Grooves in holes are recessed by a swing toolholder or recessing toolholder. These holders require the following operating cycle: longitudinal advance to run the tool into the hole, radial feed to the required depth, longitudinal working feed, tool withdrawal (radial) from the recess, and finally longitudinal tool withdrawal from the hole.

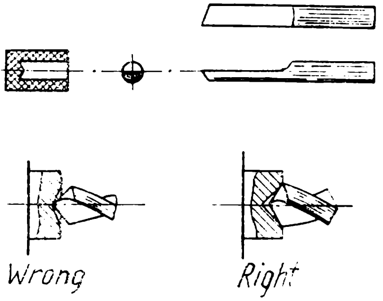


Fig. 121. Spotting holes and drilling deep holes.

Internal tapers are turned with combined movements of the cutting tool controlled by a taper turning attachment or they are machined with roughing and finishing taper reamers.

External thread may be cut with self-opening die heads (Fig. 122 *a*), round dies (Fig. 122 *b*), multiple-point chasers, and thread rolls. Die heads are used, as a rule, for long thread and round dies for short thread. Thread in back of a shoulder is cut with a chaser or it is rolled. Thread chasing is a highly accurate but slow method of cutting thread. Round dies, as well as solid taps, must be backed off or out of the work. This will require reverse rotation of the work spindle.

Threads are rolled only on comparatively soft materials or in cases when the threads are located in back of a shoulder.

Thread should be cut before the cross-section has been reduced to any extent by the cut-off tool. Often threading is done on special automatic thread rolling machines.

Knurling may be performed both from a cross slide and from the turret. In any case, a back rest or second knurl is required opposite the knurl to give a balanced cut (Table 18). The knurls are swivelled in reference to each other to obtain a diamond pattern. Long surfaces are knurled with supplementary longitudinal feed movement. If possible, knurling is not combined with other operations.

The application of special attachments considerably extends the processing capacity of automatic screw machines.

The screw slotting attachment may also be employed for milling flats on screw heads if two cutters are installed. Certain automatics accommodate an attachment which enables the rear end of the work to be milled. It operates with a swivelling grip arm.

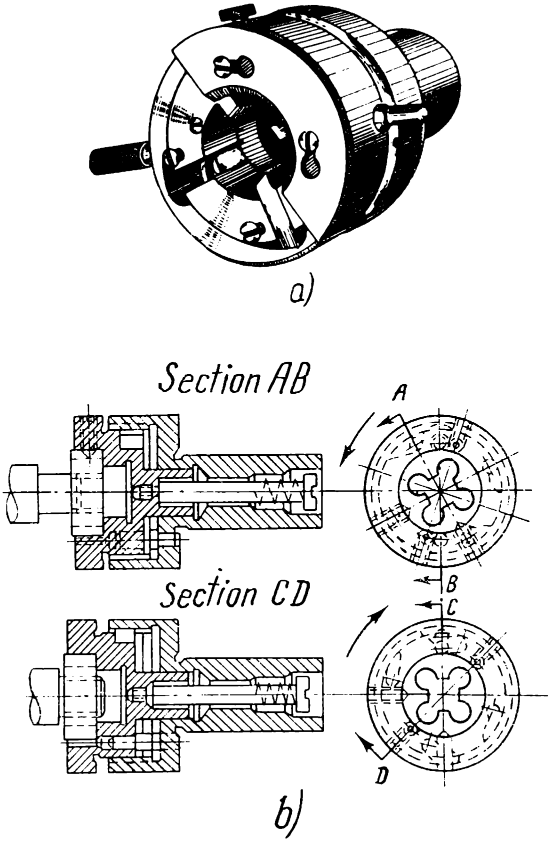
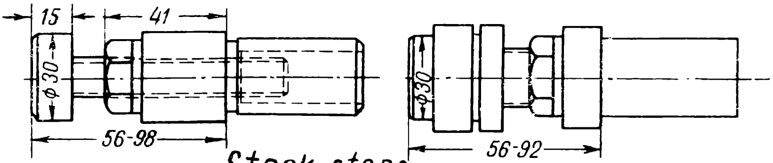
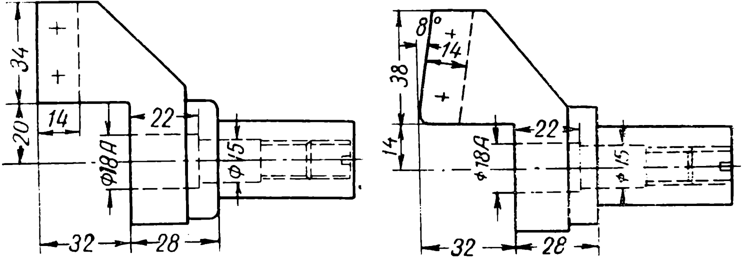


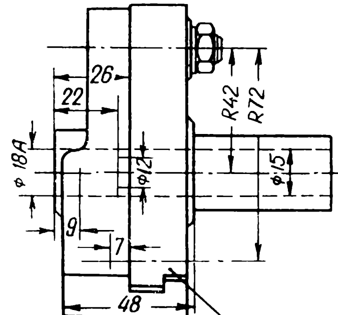
Fig. 122. Self-opening die head and round die.



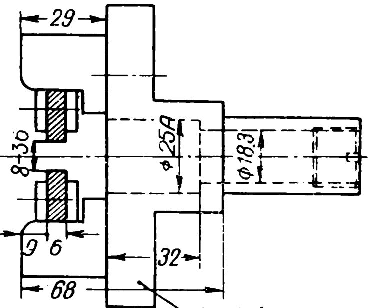
Stock stops



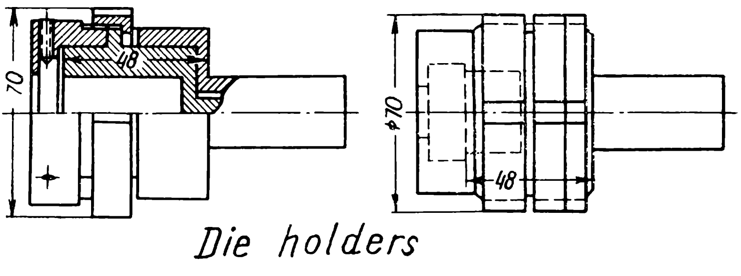
Knee and



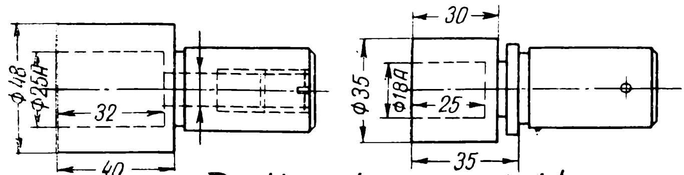
Swing toolholder



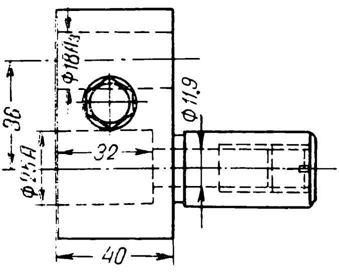
Knurl holder

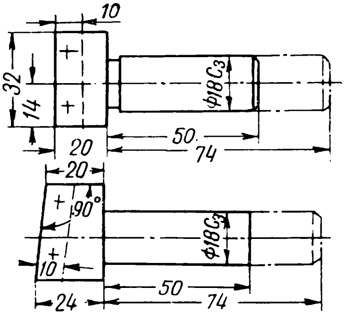


Die holders

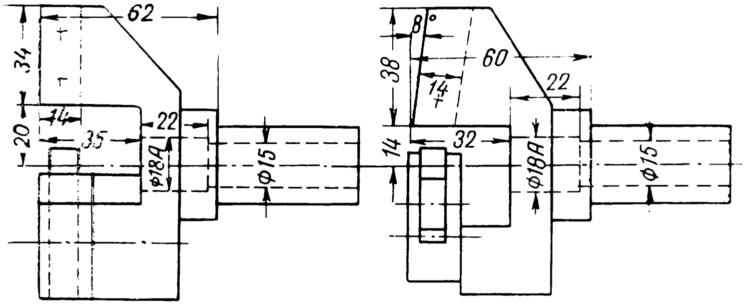


Drill and reamer holders

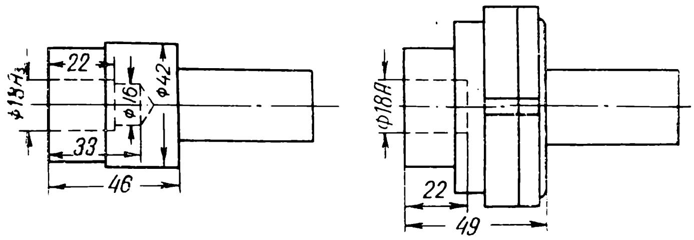




Angle tool holders



Box toolholders with back rests



Tap holders

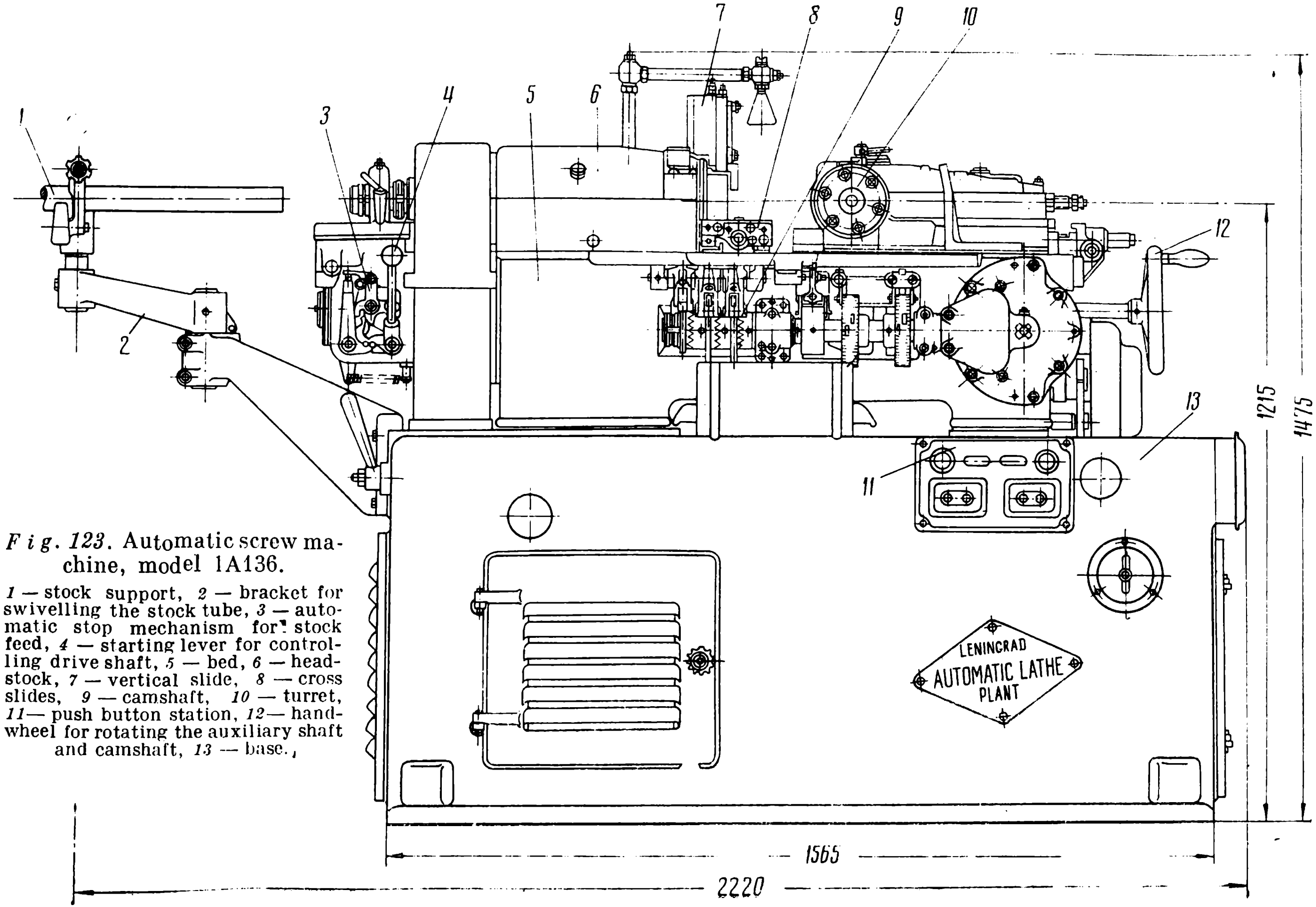


Fig. 123. Automatic screw machine, model 1A136.

1 — stock support, *2* — bracket for swivelling the stock tube, *3* — automatic stop mechanism for stock feed, *4* — starting lever for controlling drive shaft, *5* — bed, *6* — headstock, *7* — vertical slide, *8* — cross slides, *9* — camshaft, *10* — turret, *11* — push button station, *12* — handwheel for rotating the auxiliary shaft and camshaft, *13* — base.

Holes are drilled in the rear end of the work by a special attachment driven from the auxiliary camshaft. This attachment may also be used for countersinking or chamfering on the rear end.

A special work spindle brake is used in conjunction with the cross drilling attachment. The drilling attachment is mounted at the rear of the bed in this case.

§ 86. AUTOMATIC SCREW MACHINES, MODELS 1A124 AND 1A136

At the present time, new Soviet models of automatic screw machines are available. They have bar capacities of 12, 18, 25, 36 and 40 mm. They are more powerful, operate at higher speeds, and have higher production capacities than previous models.

The specifications of this series of automatics are listed in Table 17.

The construction of these automatics and their setting up is very much the same and, therefore, a study of model 1A136 (Figs. 123 and 124) will be quite sufficient.

The main drive of model 1A136 (Fig. 125) is from a D. C. electric motor supplied from a converter with adjustable voltage.

The converter is fastened on a separate plate located between the machine and the stock support. The box-shape base of the machine

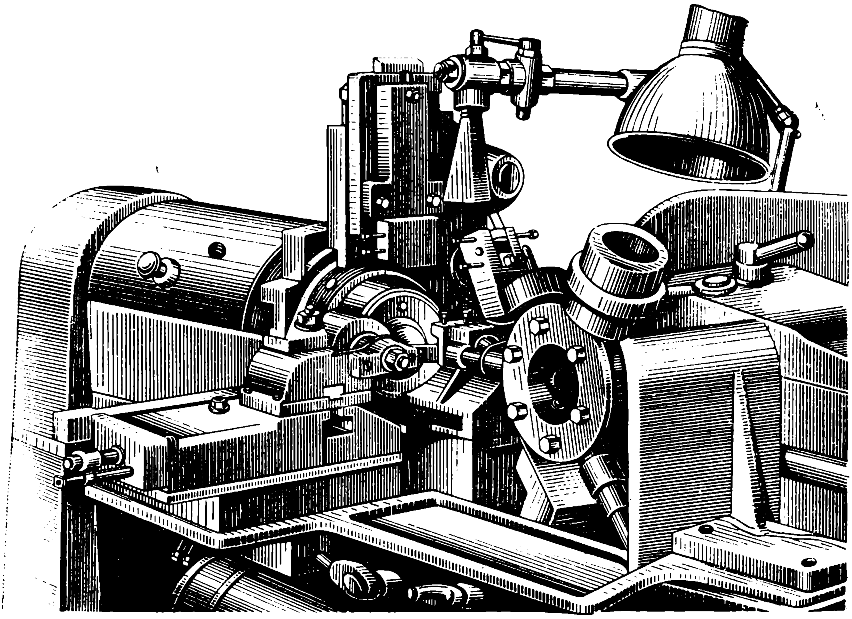


Fig. 124. Working zone of the automatic screw machine, model 1A136.

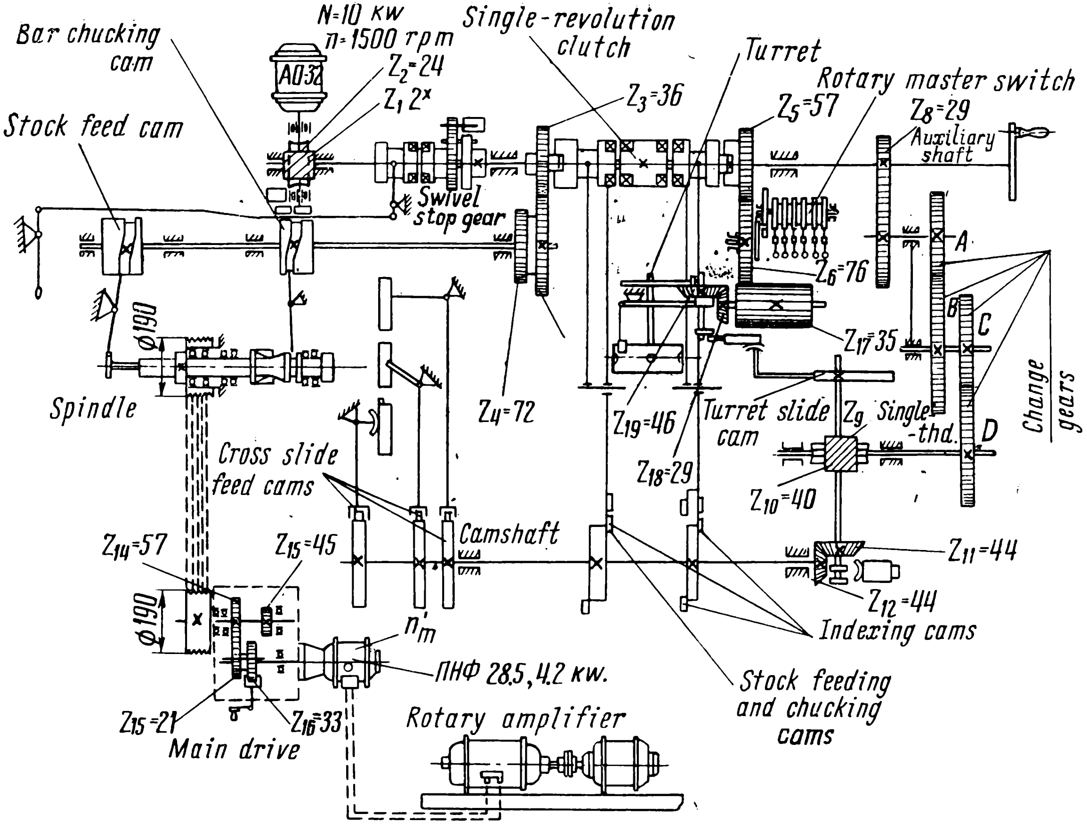


Fig. 125. Gearing diagram of the model 1A136 automatic.

contains the D. C. motor with a reducing gear, mounted on a baseplate. The reservoir in the base holds the cutting fluid. The electrical equipment cabinet and a setting up panel are located at the right in a recess. The bracket of the stock support tube is secured to the left end face of the base. The reducing gear is a two-shaft, two-stage unit with the gearing ratios 1 : 1.36 and 1 : 2.71. A pulley, mounted on the output shaft, transmits rotation to the work spindle through V-belts.

The main drive provides for an infinitely variable range of spindle speeds from 60 to 2,000 rpm. Any speed within this range may be obtained for any turret position and the spindle speeds are changed automatically upon turret indexing. Previously set up trip dogs consecutively engage six limit switches of the electrical circuit.

The spindle (Fig. 126) is mounted in preloaded radial roller bearings which prevent excessive clearance (play) in the spindle over a prolonged period of operation. When clearance exceeds the permissible value, due to wear, the outer spacer ring between the bearings in the rear support should be ground down 0.02 or 0.03 mm. Strict parallelism must be maintained on the ring faces.

The driving pulley *6* runs on separate ball bearings mounted on a rigid flange. The pulley is linked to the spindle with a key. Spindle reverse, required in thread cutting, is obtained by the action of trip dogs on a limit switch. If two threads are to be cut on a workpiece, one pair of trip dogs is used for one thread and another pair for the second thread.

Stock feeding and chucking. The spindle has slots in the central part, between the bearings, which accommodate the chuck levers *10*. One end of the levers bears against the end face of the chucking tube *11* while the other end enters a sleeve with an internal tapered bore.

The stock feeding tube *5* is arranged inside the spindle. One end of this tube is secured in a ball bearing which is mounted in the housing of the stock feeding slide *2*. An interchangeable stock feeding finger *15* is screwed on the other end of the tube. Stock feeding and chucking is controlled from a cam drum (see Fig. 125). Motion is transmitted from the cams to the stock feed slide and chucking sleeve through lever systems. The cams on the drums are arranged so that the stock feeding slide is first traversed to the left over the length of preset stock feed.

When the slide stops, the chucking sleeve *9* is shifted to the right to release the levers *10*. Under the action of spring *13*, the ends of the levers enter a recess in the sleeve. This opens the interchangeable spring collet *17* to release the bar. After this, the stock feeding slide travels to the right and feeds out the bar stock to the stop, while the chucking sleeve is shifted to the left. The sleeve depresses the levers and forces the tube and sleeve forward to close the collet on the bar. This cycle is repeated each time a finished workpiece is cut off. The amount of stock feed is adjusted with a screw (see section *AA*

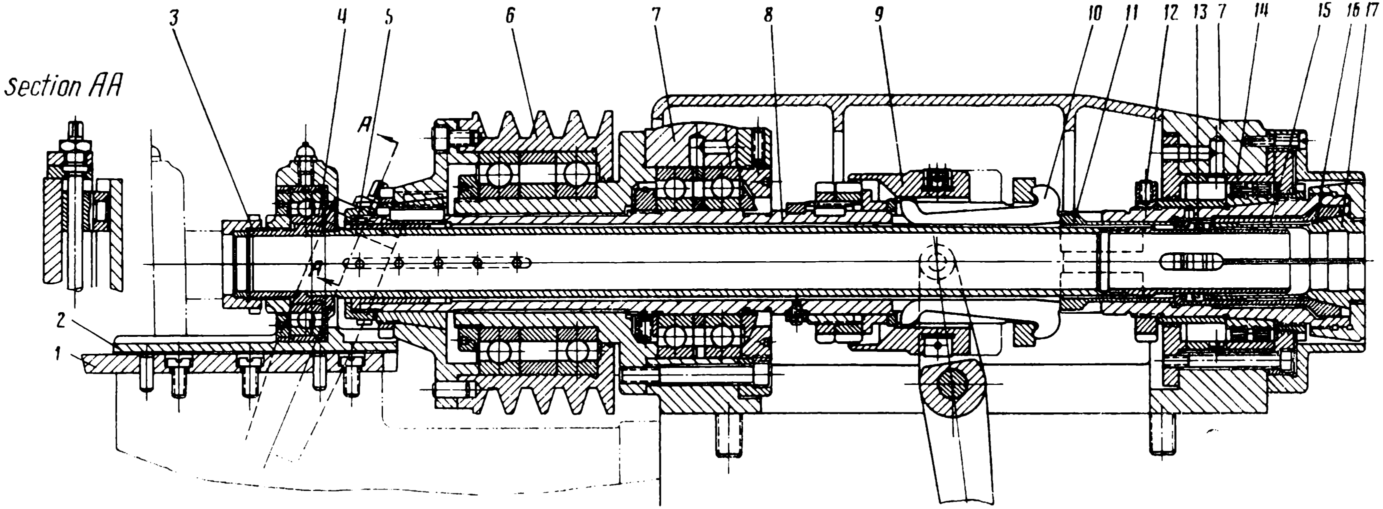


Fig. 126. Section through the spindle of the model 1A136 automatic.

1 — bracket for slide, *2* — stock feed slide, *3* — bushing with bearing *4*, linked to tube *5* on which the stock feeding finger *15* is screwed, *6* — driving pulley, *7* — headstock housing, *8* — spindle, *9* — sliding sleeve for closing chuck which operates the chuck levers *10*, which, in turn, push the tube *11* and sleeve *16* to close the spring collet *17*, *12* — nut for adjusting the bearing *14*, *13* — spring.

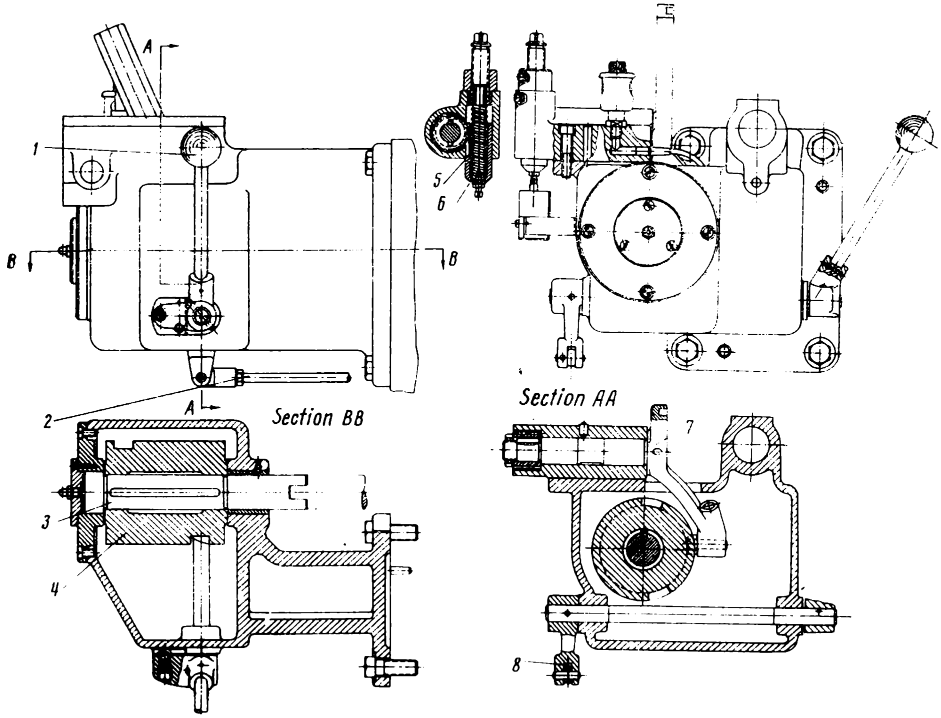


Fig. 127. Mechanism for engaging stock feed on automatics, models 1A124 and 1A136.

in Fig. 126) which shifts a slide block along the slot of a lever. Two nuts at the left of the chucking sleeve adjust the clamping force of the chuck (principles of operation of the stock feeding and chucking devices are shown in Figs. 78 and 79).

The stock feed mechanism is arranged in a cast-iron housing (Fig. 127). Shaft *3* carries the drum *4*, stock feed lever and the automatic stop mechanism which operates when a bar has been used up.

In stopping by hand, lever *1* is shifted counterclockwise. A ball-click device indexes the lever in either the engaged or disengaged positions.

Lever *8*, mounted rigidly on the same shaft with lever *1* but at the rear of the housing, is linked through tie-rod *2* with a lever which either engages the claw clutch of the drive shaft to the clutch member *4* of the auxiliary shaft (Fig. 127) or disengages it. The lever is turned clockwise to start the automatic.

During automatic operation, while the bar length is still sufficient for feeding out and chucking, the feeding finger slides back along the bar when the feeding slide is retracted. The roller of lever *7* contacts the left side of the cam groove on the feeding drum *4* holding spring *5* under tension. This spring is linked to the lever through a rock and gear segment, keyed on the lever shaft. The pressure of the spring however is less than the drag of the feeding finger when drawn back over the bar. When the bar is used up, the drag of the feeding finger ceases and spring *5* retracts lever *7* in a counterclockwise direction, so that its roller enters a recess in the cam drum groove. Rack *6* depresses the pin of the limit switch, type MII-3, and switches off both drive motors.

Drive of the auxiliary control shaft and camshaft (Fig. 128). All working and idle movements of the automatic are controlled by the camshaft and auxiliary control shaft. They are driven from an individual electric motor through worm gearing *1* of the reducing gear. The auxiliary control shaft *2* is located behind the bed and rotates at constant speed (120 rpm). It carries clutch *4* for hand engagement by means of the shifting fork *3*, safety coupling *6* with a breakable pin, a 36-tooth gear transmitting rotation through the 72-tooth gear to shaft *7* on which the stock feeding and chucking cam drums are mounted (see also Fig. 125), as well as the swing stock stop *8*, and a 57-tooth gear for driving the turret rapid traverse and indexing mechanisms through a 76-tooth gear (see Fig. 125). All of these items are mounted freely on the shaft and may be engaged by the clutch members *9* and *10*.

Mechanisms for auxiliary (idle) movements are engaged and disengaged by single-revolution clutches (the principle of these clutches is described in detail in § 22 and Fig. 44) which are controlled by cams mounted on drum *20* through lever *21*. Lever *11* locks clutch member *9* in the disengaged position.

A full cycle of stock feeding and chucking movements takes place during one revolution of drums *5*; the auxiliary shaft makes two revolutions in the same time.

To prevent premature disengagement of clutch members *9* and *10*, levers *11* and *21* are held in the disengaged position by an eccentric pin. Rotation for rapid traverse movements of the turret is obtained, as mentioned above, from the auxiliary control shaft through an intermediate gear and the turret slide gear.

The turret is indexed one position in $^1/_6$ revolution of the Geneva wheel; the auxiliary shaft makes $1^1/_3$ revolutions in the same time.

If two consecutive turret indexings are required during the cycle, two trip dogs are mounted on opposite sides of drum *18*.

The camshaft is driven from the auxiliary control shaft (Fig. 128). The camshaft comprises two sections, a longitudinal section *19*, arranged in front of the bed, and a transverse section *15*. The speed of the camshaft is set up by two pairs of change gears $(\frac{A}{B} \times \frac{C}{D})$. Plate cam *13*, mounted on the transverse camshaft section *15* and

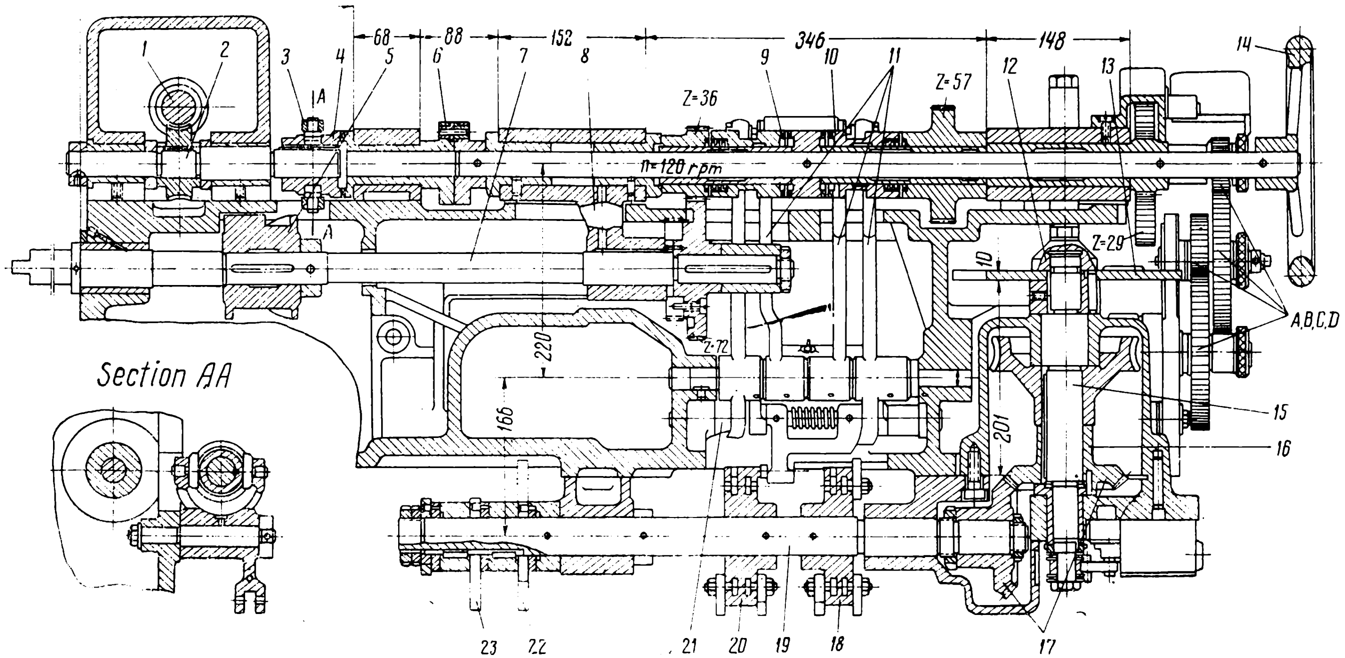


Fig. 128. Section through the auxiliary control shaft and camshaft of automatics, models 1A124 and 1A136.

1 — worm gearing for driving auxiliary shaft *2*, *3* — fork for engaging clutch *4*, *5* — stock chucking cam drum, *6* — safety coupling with a breakable pin, *7* — shaft carrying the stock feeding and chucking (*5*) cam drums, as well as the swing stock stop *8*, *9* and *10* — members of the double-claw single-revolution clutch controlled by levers *11* and *21*, *12* — nut holding the plate cam *13* on the transverse section of the camshaft *15*, *14*—handwheel for rotating the auxiliary shaft and the camshaft, *16* and *17* — bevel gearing linking together the camshaft sections *19* and *15*, *18* and *20* — drums with trip dogs for controlling levers *21* and *11*, *22* and *23* — cross slide cams.

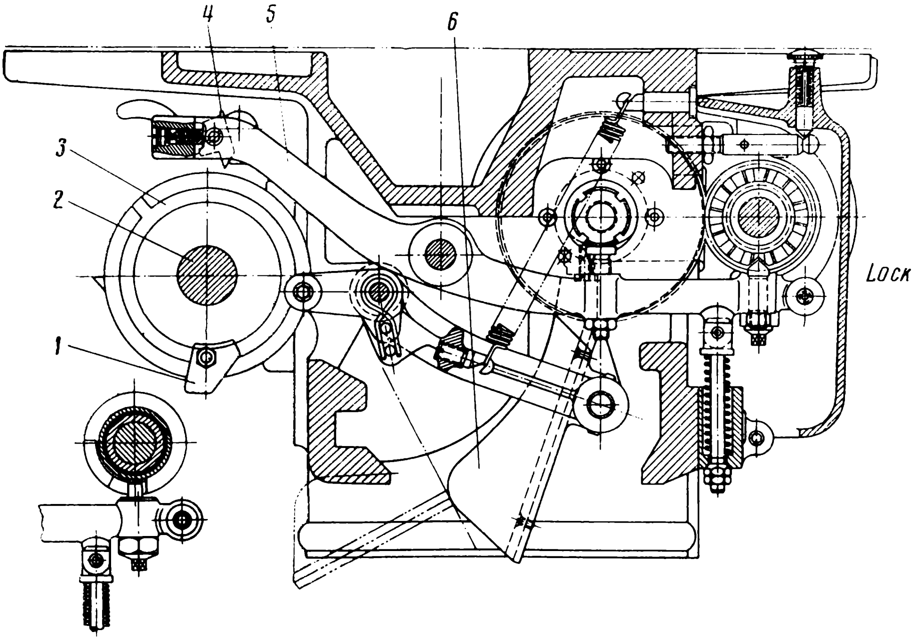


Fig. 129. Work chute operating mechanism for automatics, models 1A124 and 1A136

held by nut *12*, traverses the turret slide through a lever, gear segment, and a rack. Cams *22* and *23*, controlling cross slide movement, are mounted on the longitudinal section *19*. This section also carries a cam for the third vertical slide (not shown) as well as cam drums *18* and *20* which control the operation of the single-revolution clutches on the auxiliary shaft. The left end of the camshaft overhangs its bearing and this enables cross slide cams *22* and *23* to be changed without disassembling the camshaft (in older designs of automatics, the camshaft consisted of two halves linked with a coupling; shifting the coupling to the left revealed a gap between the camshaft halves which was used to insert the cams). Cam drums *18* and *20* remain constantly on the camshaft and are set up by adjustment of trip dogs in the drum slots.

Finished and cut-off work is carried by a chute *6* (Fig. 129) to the strainer pan. The chute is held in its extreme idle position, when not in actual operation, by a spring so that it does not hinder chips from dropping into the pan.

At the moment the finished work is cut off, an adjustable trip dog on drum *3*, rotating together with the camshaft *2*, actuates a lever which turns the chute to the working position so that it catches the falling workpiece which slides down to the strainer pan. A spring returns the chute to its initial position.

Turret slide. The turret slide *2* (Fig. 130), carrying the turret, reciprocates along the guideways *1*, held by screws to the bed. The turret has six tool holes. Tools are clamped in the holes by a split bushing and a binding screw.

The plate cam *13* for turret travel is mounted on the camshaft and is located by a driving pin which enters a 10 mm hole in the cam. Then the cam is secured by a nut. In this manner, the cam is definitely positioned in reference to the zero lines on the cam, claw clutches, cross slide cams, and control cam drums.

The turret slide receives its forward movement from cam *13* on the camshaft through lever *15* with the segment gear which meshes with the hollow rack *7*.

The slide is retracted by a spring inside the slide.

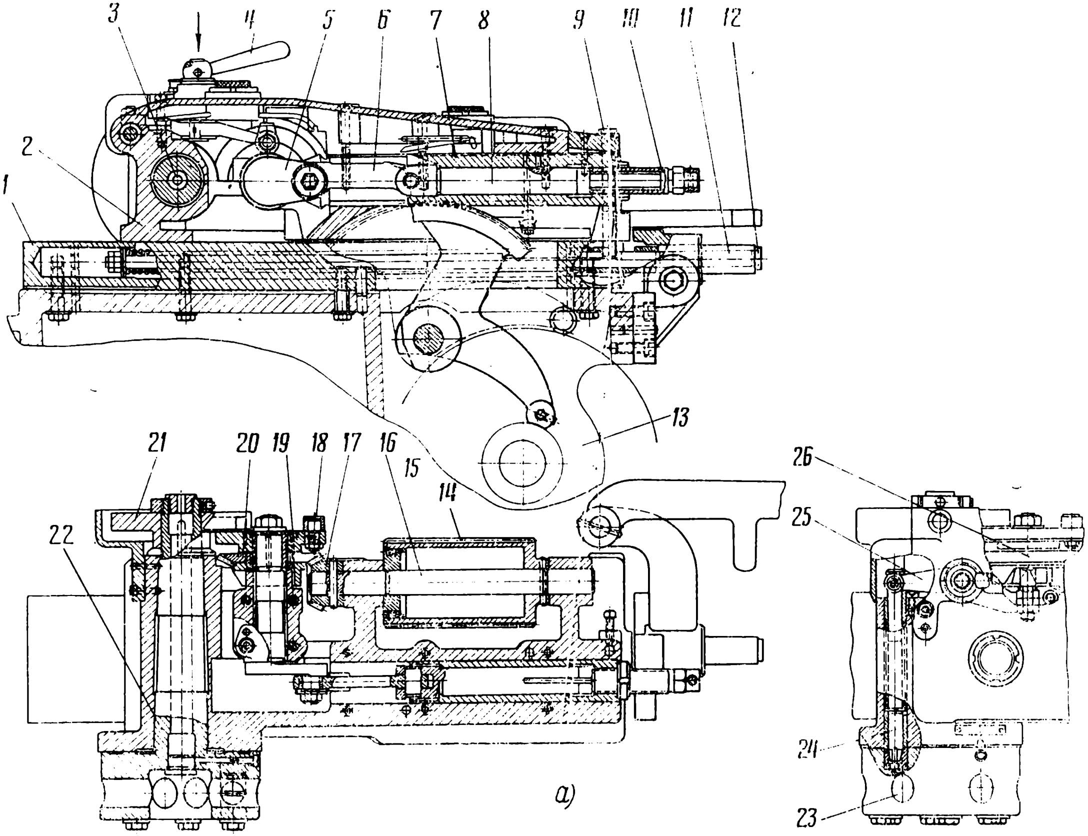
The turret is automatically indexed and locked in position by the action of the auxiliary control shaft.

The complete cycle of turret slide travel, turret indexing and locking occur in the following manner:

Upon rotation of cam *13*, the roll of lever *15* follows the cam lobes. The lever rocks on its pivot and moves the hollow rack *7* by means of the segment gear. The hollow rack contains the rod *10*, one end of which passes through a bushing screwed into the end of the rack. The rod is held in the bushing by a nut. The other end of the rod is linked to connection *6* of the crank *5*. When the turret slide travels forward, the driver of the Geneva wheel is in its extreme position as shown in Fig. 130. In this position, the crank *5*, connection *6*, and rod *10*, linked to the hollow rack, constitute an integral unit, rigidly linked to the turret slide. Therefore, movement of the hollow rack *7* will advance the slide as well.

At the same time, a pin, press-fitted in the slide and entering a slot of bushing *11*, pulls the bushing forward to compress a spring mounted on rod *12*. This rod passes through bushing *11*. The action of the spring forces the slide backwards and thus holds the roll tightly against the cam surface. At the end of the working travel, the roll passes from the rise to a drop on the cam and the spring retracts the turret slide over a distance controlled by the drop on the cam.

During slide retraction to the extreme rear position, face cam *26* withdraws the locking pin *24* from a hole in the turret *23* by means of the double-arm lever *25*. In the extreme end position of the turret, roll *18* of driver *19* enters a slot of Geneva wheel *20* and indexes the turret to its next position. After this, the follower toe of lever *25* drops into a recess on its cam and the locking pin *24* will be released. The spring sends the pin forward to lock the turret in the new position. Crank *5* continues to rotate to its rear right-hand position and moves the turret slide into position for the next operation element. This completes $^1/_6$ of the turret cycle.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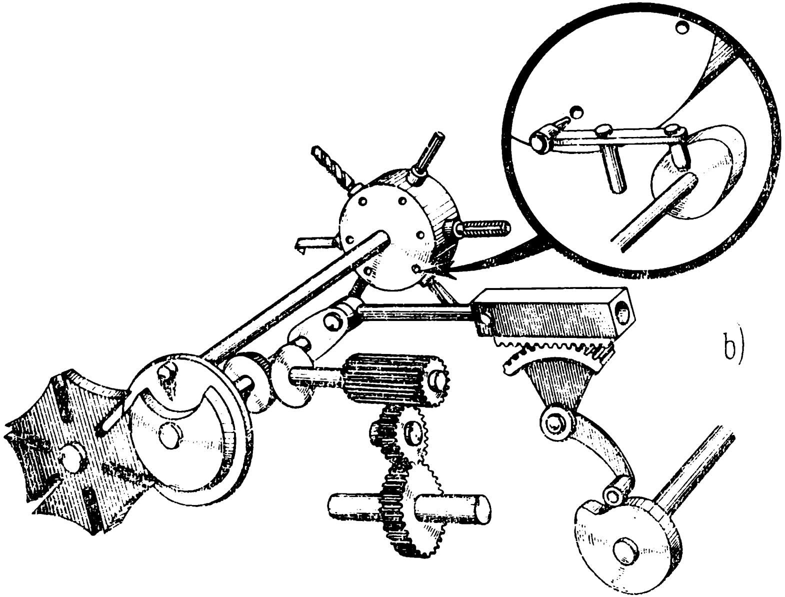


Fig. 130. Turret slide of automatics, models 1A124 and 1A136.

a—construction: *1*—bracket with guideways, *2*—turret slide, *3*—turret axis, *4*—lever for clamping the turret slide, *5*—crank with connection *6* and rod *8*, *7*—hollow rack meshing with segment gear of the double-arm lever *15*, which is actuated by cam *13*, *9*—pin, *10*—rod, *11*—bushing with rod *12*, secured in bracket *1*, *14*—wide gear of shaft *16* for driving turret indexing and locking, as well as rapid traverse movements of slide *2*, *17*—bevel gearing on shaft *16* for rotating the driver *19* with roll *18* which enters the Geneva wheel slots, *21*—nut for holding the Geneva wheel on shank *22* of turret *23*, *24*—locking pin withdrawn by lever *25* and actuated by face cam *26*; *b*—schematic view of the turret slide.

The above-described operation is repeated for each consecutive tool mounted in the turret.

If only three positions of the turret are employed, double indexing is resorted to, i. e., indexing through 120°. For this purpose, a second roll is added on disc *19* and the toe on the lever is turned through 180°.

The turret may be indexed by hand in setting up the automatic by pulling the handle toward the operator and then rotating the turret as required.

The position of the turret slide may be adjusted in reference to the work collet, by means of a bushing, within 36 mm without altering the total travel (80 mm).

The turret slide is adjusted by first releasing the screw and nut of rod *10*. The lever is held against the shoulder of the rod and the bushing is rotated in the required direction. Upon this, rod *8*, and the complete slide, are adjusted in reference to the stationary hollow rack *7*. The nut and screw are retightened after making the adjustment.

Cross slides. The cross slides *2* (Fig. 131) travel in detachable cast-iron ways *3*, secured to the bed by screws *4*.

The travel of slides *2* and *8* is controlled by cams *12* and *13* of the camshaft through levers with segment gears *5*, *6*, and *7*.

The front cross slide obtains its travel from lever *11* with segment gear *5* which meshes with a rack fastened to the slide. The slide is retracted by spring *16* which is compressed when the slide advances. The spring bears against a pin that is press-fitted in the headstock housing.

The back cross slide is operated by the levers with segment gears *6* and *7*. The vertical slide, when installed, is operated in the same manner.

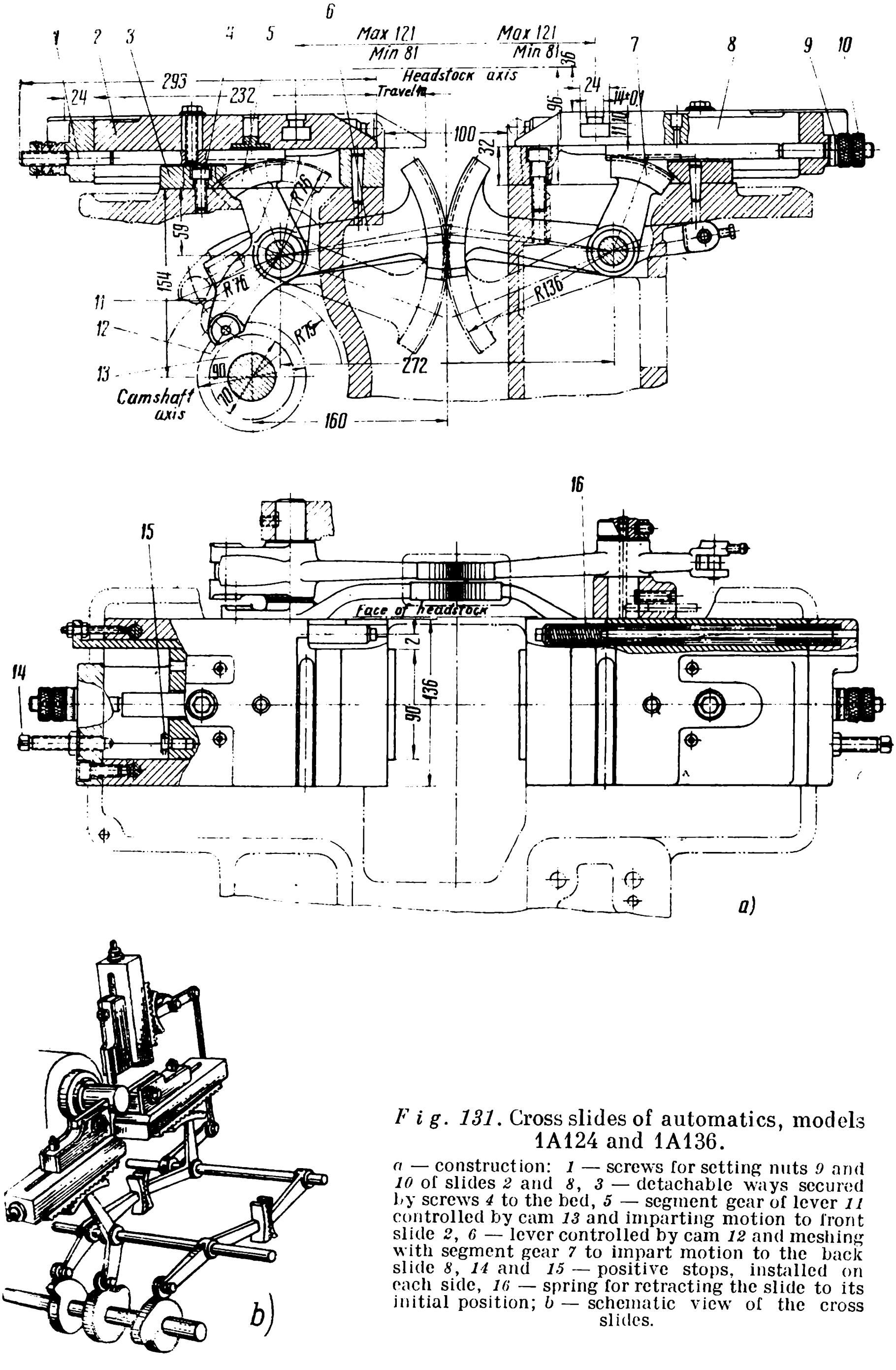
The cross slides are adjusted in reference to the spindle axis by loosening the screw and turning nut *9* in the required direction. This adjusts the slides in relation to the racks. The screw is drawn up tight after making the adjustment.

Holes are provided in the levers for a special rod used to turn the segment gears to obtain manual movement of the slides in setting up.

Tool posts are held by T-bolts in the T-slots of the slides.

Positive stops *14* and *15*, adjusted as required in setting up the machine, enable high accuracy work to be turned by the cross slides. Care must be taken not to overstrain the cross slide mechanism when setting these stops.

Coolant system. A gear pump, type ШС-8, is mounted on the lower part of the rear wall of the bed. It delivers oil from the reservoir through a pipe-line to the cutting tools. The reservoir is replenished through a hole in the top of the base. The pump is driven from the worm shaft of the reducing gear through spur gears.



F i g. 131. Cross slides of automatics, models 1A124 and 1A136.

a — construction: *1* — screws for setting nuts *9* and *10* of slides *2* and *8*, *3* — detachable ways secured by screws *4* to the bed, *5* — segment gear of lever *11* controlled by cam *13* and imparting motion to front slide *2*, *6* — lever controlled by cam *12* and meshing with segment gear *7* to impart motion to the back slide *8*, *14* and *15* — positive stops, installed on each side, *16* — spring for retracting the slide to its initial position; *b* — schematic view of the cross slides.

The reservoir has a partition and a screen for separating the metallic dust and fine chips and for settling the cutting fluid. The fluid is drawn up by the pump through a filter.

The mechanisms of the automatic are lubricated in certain places manually and in others by a centralised force-feed system from a pump.

Special attachments. The processing capacity of automatic screw machines can be considerably increased by these devices. The most important of them are the magazine-feed, screw slotting, and high-speed drilling attachments, supplementary swing stop, outside feeding attachment, and the bar restocking attachment.

The screw slotting attachment, besides slotting, can also mill the flats on screw heads and perform other simple milling operations. This attachment is mounted at the front of the automatic. It is driven from the auxiliary camshaft through bevel gearing and a pair of spur change gears, used to set up the cutter spindle speed. Movements of the arm to pick up and transport the piece and to feed it forward while the slot is being milled are controlled by cams on the camshaft. For milling slots and flats on the front end of the workpiece, the grip arm with the work is swivelled through 180°. Except for this, the milling operation is the same as for the rear end of the work.

The rear end drilling attachment, as the name implies, is used to drill, chamfer, countersink, etc., holes in the rear or cut-off end of the work. It consists of a drive, tool spindle, and feed mechanism. The attachment is driven from the auxiliary camshaft. In operation, the work is gripped in a chuck before being cut off. It is then carried by an arm to the cutting tool. After drilling (or chamfering, etc.) the workpiece is ejected from the chuck. The longitudinal and swivelling motions of the arm are obtained from two cams.

The high-speed drilling attachment (Fig. 132), for drilling small holes, has spindle rotation in a direction opposite to work spindle rotation. The bearing housing of the drive shaft is secured to the turret Geneva wheel with a collar. The shaft is driven from a device fastened on the rear wall of the headstock and powered through a roller chain from the auxiliary camshaft. A pair of change gears in the driving device enables two different ranges of drilling spindle speeds to be obtained.

Rotation is transmitted from the shaft through a sleeve, bevel gearing, drive shaft, and another pair of bevel gears to the drilling spindles which may be installed in one or several tool holes of the turret. The attachment travels with the turret during operation and its linkage to the driving device is achieved through a sliding key in the sleeve.

In *cross drilling*, *milling*, *or slotting*, the workpiece is held stationary during machining by the spindle brake. A cross drilling attachment is mounted on the back cross slide; a slotting tool or milling cutter is mounted in the turret. The spindle brake is fastened on the rear wall of the headstock while a disc with brake shoes is mounted on the spindle. The spindle brake is controlled by a cylindrical cam on the auxiliary camshaft. This cam replaces the cam drum for changing spindle speeds.

A magazine feeding attachment (see Fig. 81) may be installed on automatic screw machines for second operation work or for separate precisely forged or cast blanks. The design of such attachments depends on the form of the workpiece. Typical designs were described in § 48. These attachments may, in certain cases, be installed at the rear of the spindle.

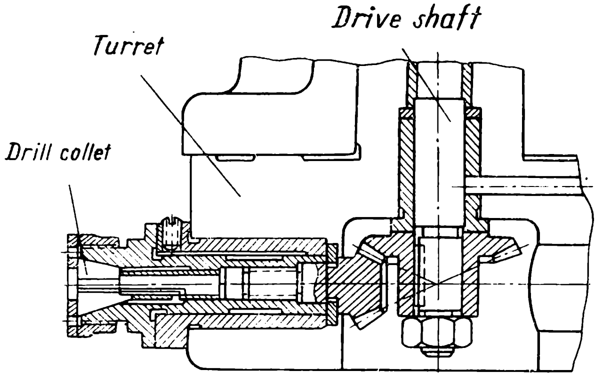


Fig. 132. High-speed drilling attachment.

The stock stop is usually mounted in the turret. Frequently, in turning complex work, all the turret holes will be required for cutting tools. In these cases, a supplementary swing stop is installed. When the stock feed begins, the stop swings down to the spindle axis; when the collet closes, the stop swings upward, out of the way of the other units.

The outside feeding attachment (Fig. 133) is used for feeding stock larger in size than the nominal bar capacity of the automatic. In this case, the feeding tube and finger are removed from the spindle and the feeding finger *2* (stock pusher) is installed outside of the spindle at the rear, being attached directly to the slide *1* which ordinarily operates the feeding tube.

After the piece of stock becomes too short to be reached by the feeding finger, the bracket of the attachment is swung up into position on pin *6* and locked with pin *7*. Then a special pusher bar is inserted to push the remaining stock through the spindle. This pusher bar is held by a ball clamp when the slide and feeding finger move to the left. The balls release the pusher bar for movement to the right. The pusher bar is pulled back to its initial position, after feeding the stock to the end, by pressing sleeve *5* forward until locking pin *4* enters a hole in the sleeve. This opens the ball clamp and allows the pusher bar to be pulled to the left out of the spindle.

Among attachments that facilitate operation of automatics, are the silent stock support and the workpiece catcher. A silent stock tube is available for automatics manufactured by the Leningrad Automatic Lathe Plant. This tube contains a wave-form spring over its full length. In certain new models, silent operation is achieved by an arrangement in which the space between two tubes is filled with sand.

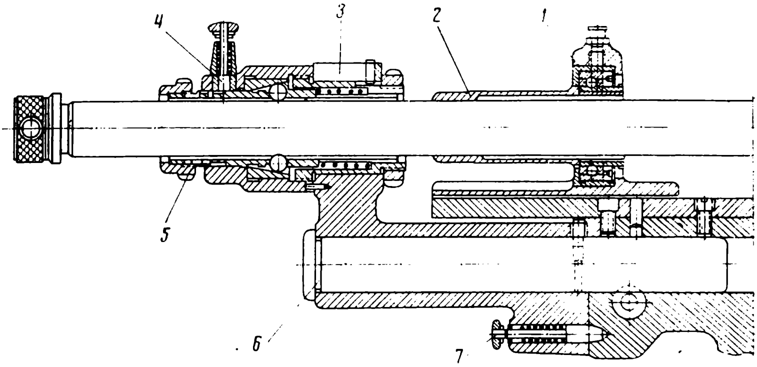


Fig. 133. Outside feeding attachment.

The bar restocking attachment (Fig. 134) greatly facilitates and speeds up restocking of round bars. The attachment is mounted on the bracket on pin *1* and is locked by pin *4*. Upon shifting the handle *7* of lever *6* to the right, the wedge-type cam *5* rotates and spreads the ends of grips *3* with self-aligning jaws that clamp the bar stock. Further movement of the lever advances the stock to the right. The lever is repeatedly swung back and forth, releasing the bar on the back motion and advancing it on the forward motion until it passes through the feeding finger and chuck collet. The grips are adjustable to the required bar size. The back or return motion of the lever and grips is effected by spring *2*.

Setting Up Automatic Screw Machines. As distinguished from earlier models, in automatics, models 1A124 and 1A136, the work spindle rotates in an infinitely variable speed range in both directions. The spindle speed and direction of rotation may be changed for each position of the turret.

In these automatics, the camshaft is powered by a separate motor through worm gearing. The auxiliary shaft operates at a constant speed of 120 rpm.

The camshaft (see Fig. 125) is driven through a constant pair of gears *29*, two pairs of change gears, *A*, *B*, *C*, and *D*, and worm gearing.

The camshaft speed n_{cs} is determined from the formula:

$$n_{cs} = n_{as}\,\frac{Z_8}{Z_7} \times \frac{A}{B} \times \frac{C}{D} \times \frac{Z_9}{Z_{10}} = 120\,\frac{29}{79} \times \frac{A}{B} \times \frac{C}{D} \times \frac{1}{40} = 1.1\,\frac{A}{B} \times \frac{C}{D} \text{ rpm}$$

in which A, B, C, and D are the number of teeth on the change gears; n_{as} is the speed of the auxiliary shaft, 120 rpm.

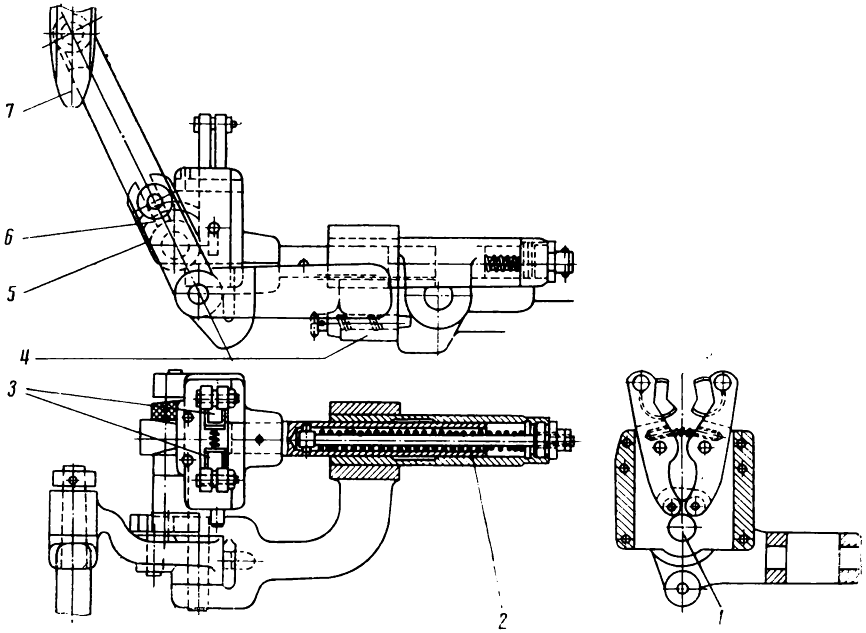


Fig. 134. Bar restocking attachment.

Work is finished in one revolution of the camshaft. Therefore, the time in seconds to make one piece T_c is determined from the formula:

$$T_c = \frac{60}{n_{cs}} = \frac{60}{1 \cdot 1} \times \frac{D}{C} \times \frac{B}{A} = 54 \cdot 5\,\frac{D}{C} \times \frac{B}{A} \text{ sec.}$$

After computing the cycle time T_c for the given workpiece, the change gears are calculated by the formula:

$$\frac{A}{B} \times \frac{C}{D} = \frac{54 \cdot 5}{T_c}.$$

The stock feeding and chucking mechanism is driven from the auxiliary shaft through gears *15* and *16*.

The speed n_{fc} of the drums of the stock feeding and chucking mechanism is constant and is calculated from the formula:

$$n_{fc} = n_{as}\,\frac{Z_3}{Z_4} = 120\,\frac{36}{72} = 60 \text{ rpm.}$$

The bar stock is fed out and chucked in one revolution of the drums and therefore this operation will require:

$$t_{fc} = \frac{60}{60} = 1 \text{ sec.}$$

The spindle is reversed and its speed is changed automatically during turret indexing.

The turret is indexed a single position during one revolution of the driver and $^1/_6$ revolution of the Geneva wheel. Driver rotation is obtained along the following gear train: from the shaft through gears with 57, 76 and 35 teeth, and bevel gears with 22 teeth. The disc with the driver is fastened to the last bevel gear. The time in seconds t_{ti} required for one turret indexing ($^1/_6$ revolution) is determined by the formula:

$$t_{ti} = \frac{60}{n_{as}} \times \frac{1}{i} = \frac{60}{120} \times \frac{35}{57} \times \frac{46}{23} = 0.667 \text{ sec},$$

in which i is the gearing ratio from the auxiliary shaft to the driver.

Any spindle speed in a range from 60 to 2,000 rpm may be set up for each position of the turret. For example, a diameter of 36 mm may be turned from the first turret position with a spindle speed of 420 rpm and the corresponding cutting speed of 47.5 m per min. A smaller diameter (24 mm) on the same workpiece is machined by a tool in the second turret position at a spindle speed of 700 rpm and a cutting speed of 52.5 m per min, etc. It is evident that the most expedient speed may be selected for each operation element. The spindle speeds are set up by six handles on the setup panel of the automatic and they change automatically in the course of the operation.

The direction of spindle rotation may also be changed from position to position. Thus, thread may be cut with a tap or die in any turret position. It is not advisable to cut thread close up to a shoulder or to tap blind holes, since setting the length of thread-cutting tool travel is very complex and tool breakage is probable.

Calculations of a setup for these models of automatic screw machines are similar to those required for models 1136, 1124, Index, Skoda, and others given in § 54 but due consideration must be given to the special features of models 1A124 and 1A136.

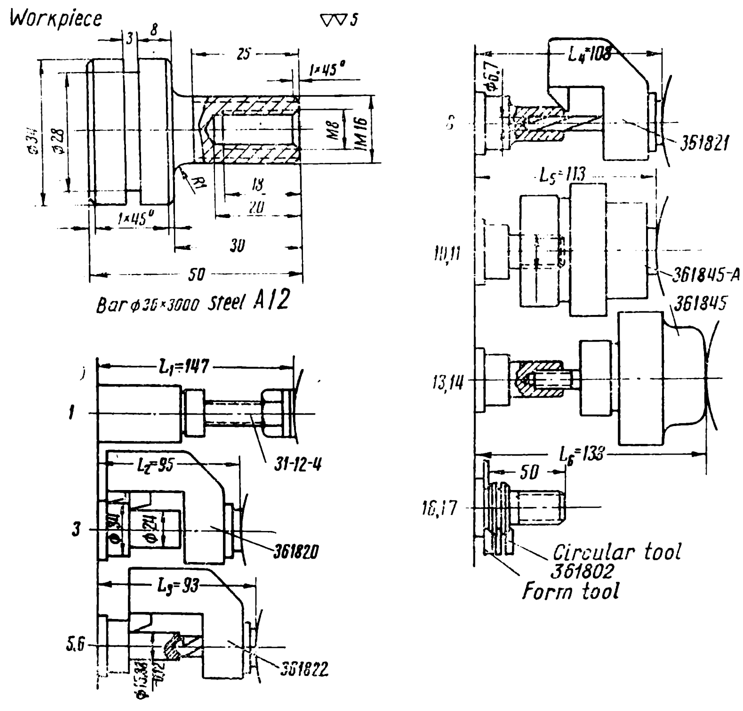
§ 87. SETUP FOR THE AUTOMATIC SCREW MACHINE, MODEL 1A136

The tooling layout (Table 19) includes sketches of each operation element beginning with stock feed. The cutting tools and holders are shown schematically in their final working positions. The lengths of the cutting tools with their holders are set down; one to five millimetres is added in each case to compensate for errors in setting up the automatic and in manufacturing the cams.

Table 19

Tooling Layout and Operation Sheet for the Automatic Screw Machine, Model 1A136

Tooling layout



Cutting fluid		Sulphurised oil	
Operation element	Cutting speed v, m/min	Spindle speed n_s, rpm	Equivalent revolutions factor a
3 5.6 8 10 13 16	115.5; 75 72 33 5 7.5 73	1,050 1,050 1,580 100 300 680	1 1 0.665 10.5 3.5 1.54
Change gears			
A	B	C	D
20	80	60	45
Setting distance — turret to chuck face 173			

(Continued)

	Operative element	Order of operation elements	Travel l, mm (cam throw)	Feed s, mm/rev	Spindle revolutions required for each operation element: working travel	Spindle revolutions required for each operation element: after deducting overlapped motions	Plate cams, Hundredths: working travel	Plate cams, Hundredths: idle motions	Plate cams, Hundredths: start	Plate cams, Hundredths: finish	Plate cams, Radii: start	Plate cams, Radii: finish
Turret	1.	1. Feed stock to stop	—	—	—	—	—	1	0	1	60	64
		2. Index turret	—	—	—	—	—	2.5	1	3.5	63	63
	2.	3. Turn diam 34 and 24	54	0.12	450	450	15.5	—	3.5	19	64	118
		4. Index turret	—	—	—	—	—	3	19	22	88	88
	3.	5. Turn diam $15.88_{-0.12}$ and spot drill	31	0.15	207	207	7.5	—	22	29.5	89	120
		6. Dwell	—	—	—	—	—	0.5	29.5	30	120	120
		7. Index turret	—	—	—	—	—	4	30	34	81	81
	4.	8. Drill 6.7 mm, chamfer 1×45°	23	0.06	350	230	8	—	34	42	82	105
		9. Index turret	—	—	—	—	—	4	42	46	71	71
	5.	10. Cut thread 1M16×1.5	28	1.5	19	200	7	—	46	53	72	97
		11. Back off die	28	1.5	19	200	7	—	53	60	97	72
		12. Index turret	—	—	—	—	—	4.5	60	64.5	50	50
	6.	13. Tap thread M8×1.25	21	1.25	17	60	2	—	64.5	66.5	50	73
		14. Back out tap	21	1.25	17	60	2	—	66.5	68.5	73	54
		15. Index turret	—	—	—	—	—	(2)	(97)	(99)	50	50
Cross slides		16. Turn groove to diam 28	3.5	0.03	117	(180)	(6.5)	—	(68.5)	(75)	57.5	61
		Front slide: Chamfer 1.5×45°										
		Front slide: Dwell	—	—	—	—	—	(0.5)	(75)	(75.5)	61	61
		17. Vert. slide: Chamfer 1.5×45°	2.5	0.03	84	(129)	(4.5)	—	68.5	(73)	57.5	60
		Vert. slide: Dwell	—	—	—	—	—	(0.5)	(73)	(73.5)	60	60
		18. Back slide: Cut off	18.3	0.035	525	810	28.5	—	68	97	56.7	75
		Back slide: Withdraw cut-off tool	—	—	—	—	—	3	97	100	75	35

Total . . . . $n_w = 2{,}217$, $K_w = 77.5$, $K_i = 22.5$

Cycle time and production

$$n_{cycle} = n_w \frac{100}{K_w} = 2{,}217 \times \frac{100}{77.5} \approx 2{,}861 \text{ revolutions}$$

$$T_c = \frac{60 \times n_{cycle}}{n_s} = \frac{60 \times 2{,}861}{1{,}050} \approx 164 \text{ seconds.}$$

Actual production

$$Q'_a = \frac{3{,}600}{T_c} \times \eta = \frac{3{,}600}{164} \times 0.87 \approx 19 \text{ pcs per hr}$$

Setting-up rating—5

Job rating —4

Number of machines attended dy one operator—3

In machining the pipe connection of this example, the stock is fed out to a distance of 58 mm from the spindle nose to the stock stop, since the finished workpiece length is 50 mm, the cut-off tool has a width of 3 mm and is set 5 mm from the chuck face. Thus, the amount of stock feed is 53 mm.

After establishing the lengths of the turret tool holders with their tools (see § 59), the distance is determined from the turret to the chuck face for each turret position. Since the tools and holders are drawn in their final (left-hand) positions, these distances in the example will be: 3rd operation element—95 mm, 5th—93 mm, 8th—108 mm, 10th—113 mm, and 13th—138 mm.

The distance from the chuck face to the turret in its initial position (before starting the operation) equals this distance in the 3rd operation element plus the length of working travel, i. e., $95+54=$ $=149$ mm.

The setting of the turret in reference to the chuck face equals the sum of the minimum distance in all operation elements plus the maximum travel of the turret slide. In this case the setting will be $93+80=173$ mm; it should not exceed 180 mm.

Selecting cutting speeds and spindle speeds for the operation elements. After drawing the tooling layout and planning all of the operation elements, the cutting speeds are selected on the basis of the working conditions, required surface finish, and tool material employed.

The workpiece of this example is to be machined with cemented carbide tipped tools (except for the circular tool).

The selected cutting speeds for operation elements that do not overlap will be: for turning diam 34 mm—$v=115.5$ m per min (operation element 3), for turning diam 15.88 mm—$v=72$ m per min (op. element 5), for drilling 6.7 mm—$v=33$ m per min (op. element 8), for cutting off from diam 34 mm—$v=73$ m per min (op. element 16), for cutting thread 1M16×1.5—$v=5$ m per min (op. element 10), and for tapping thread M8×1.25—$v=7.5$ m per min (op. element 13).

On the basis of the cutting speeds v, the spindle speed n_s is determined for each operation element from the formula:

$$n_s=\frac{1,000v}{\pi d}\text{ rpm}$$

in which d is the diameter machined, in mm.

The nearest values of spindle speeds, listed in the service manual, are then selected instead of the computed values. They will be:

$n_s=1,050$; 1,580; 100; 300 and 680 rpm.

The following tool travel values are accepted for this example: operation element 3—$l_3=53+1=54$ mm (53 mm is the length turned, including the cut-off tool width), op. element 5—$l_5=30+1=$ $=31$ mm, op. element 8—$l_8=20+0.3\times0.7+1\approx23$ mm, op. elements

10 and 13—travels $l_{10}=28$ mm and $l_{13}=21$ mm, op. element 16a—$l_{16_a}=\frac{35-28}{2}=3.5$ mm, op. element 16—$l_{16}=\frac{34.6}{2}+1=18.3$ mm (in which 1 mm is the amount the cut-off tool passes beyond the centre) and op. element 16b—$l_{16_b}=\frac{35-30}{2}=2.5$ mm.

Determining the radii on the cam lobes. Of the previousy calculated distances from the chuck face to the turret, the minimum value 93 mm (in this example) is selected. This minimum distance indicates that in the 5th operation element at the end of the cut, the cam roll will be on the maximum radius of the turret cam, i. e., $R_5=120$ mm, on the basis of the tool travel. The radius at the start of the lobe for turning diam $15.88_{-0.12}$ will be $R'_5=120-31=89$ mm.

Using formula (41), the other lobe radii can be computed as:

$R_1=64$ mm, $R_3=118$ mm, $R'_3=64$ mm, $R_8=105$ mm, $R'_8=82$ mm, $R_{10}=97$ mm, $R'_{10}=72$ mm, $R_{13}=73$ mm, and $R'_{13}=54$ mm.

A clearance of from 0.5 to 2 mm is to be added to all tool travel values to prevent starting the cut at rapid advance speed.

The travel of the cut-off tool is increased to face off the end of the work.

The cam lobe radii for thread cutting are reduced by from 10 to 15 per cent of the thread length.

Cam lobe radii for turret indexing are reduced 1 or 1.5 mm. In this example, the turret will be indexed on radii 63, 88, 81, and 71 mm. Only the last indexing will be on a radius of 50 mm (from design considerations).

In determining the cam lobe radii for the cross slides, it must be remembered that the maximum radius $R_{max}=75$ mm and corresponds to a position of the tool cutting edge at the centre of the work. Since the tool stops 14 mm from the centre in turning the groove to a diam of 28 mm, the maximum radius on the lobe of the front slide cam for this operation element will be $R=75-14=61$ mm. At the start of this lobe, the radius will be $R'=61-3.5=57.5$ mm, in which 3.5 mm is the working travel of the circular tool.

The maximum radius on the back slide for cutting off will be $R_{max}=75$ mm, since the tool even passes slightly beyond the centre. The radius at the start of cut-off will be $R'=75-18.3=56.7$ mm, i. e., $R=75$ mm minus the working travel of the cut-off tool.

Determining the number of spindle revolutions required for the operation elements. The number of revolutions n_o is determined by the formula $n_o=\frac{l}{s}$ rev in which l is the tool travel, in mm, for the given operation element; s is the tool feed, in mm/rev selected from the tables.

The following spindle revolution values are obtained for this example:

$$n_{o_3}=\frac{54}{0.12}=450 \text{ rev} \qquad n_{o_{13}}=\frac{21}{1.25}=17 \text{ rev}$$

$$n_{o_5}=\frac{31}{0.15}=207\text{ rev}\qquad n_{o_{16a}}=\frac{3.5}{0.03}=117\text{ rev}$$

$$n_{o_8}=\frac{23}{0.066}=350\text{ rev}\qquad n_{o_{16}}=\frac{18.3}{0.035}=525\text{ rev}$$

$$n_{o_{10}}=\frac{28}{1.5}=19\text{ rev}\qquad n_{o_{16b}}=\frac{2.5}{0.03}=84\text{ rev.}$$

In thread cutting, the number of spindle revolutions equals the number of full threads to be cut.

After determining the spindle revolution values for each operation element, they are analysed to establish which are overlapped and which are not so that they can be set down in the corresponding column of the operation sheet; overlapped revolutions as put down in parentheses.

Since the different operation elements are performed at different spindle speeds, the number of spindle revolutions in the column "working travel" does not correspond to the time required for these elements. In setup calculations the equivalent revolutions are determined. They are proportional to the times required.

The basic spindle speed selected for computations is the one used in the majority of the operation elements—$n_s^b=1{,}050$ rpm. The equivalent speeds for the other elements are computed by multiplying the actual required number of spindle revolutions by the equivalent revolutions factor a. This factor a is equal to the ratio of the basic spindle speed n_s^b to the spindle speed n_s at which the given element is performed:

$$a=\frac{n_s^b}{n_s}\,.$$

For the 3rd and 5th operation elements:

$$a_3=a_5=1,\text{ for the others: }a_8=\frac{1{,}050}{1{,}580}=0.665,$$

$$a_{10}=\frac{1{,}050}{100}=10.5,\ a_{12}=\frac{1{,}050}{300}=3.5,\text{ and }a_{16}=\frac{1{,}050}{680}=1.54.$$

This enables the sum of spindle revolutions to be calculated for making one workpiece:

$$n_w=2{,}217.$$

Determining the number of hundredths required on the cams.

This calculation begins with determining the hundredths required for the idle motions. For this purpose, the time t_w required for working travel is determined:

$$t_w=\frac{n_w\times 60}{n_s^b}=\frac{2{,}217\times 60}{1{,}050}=126\text{ sec.}$$

Then the estimated cycle time will be

$$T_e=(1.1 \text{ to } 1.3)t_w \text{ or } T_e=1.2\times 126\approx 151 \text{ sec.}$$

On the basis of this value, the number of hundredths required for the idle movements may be found in tables of the service manual.

On equal sections of the cam having a single radius, the hundredths required for idle motions are determined by the time required for the operation of the various mechanisms, such as turret dwell while stock is fed to the stop and turret indexing upon advance of the cut-off tool. To determine the exact number of hundredths required for turret indexing, it is advisable to have an accurate full size drawing of the turret cam 240 mm in diam, with the hundredths drawn as arcs of a radius $r=120$ mm from centres of a circle having a radius $R=138$ mm.

If then, the templates are applied on the cam drawing, it will be easy to determine the hundredths required for turret indexing and other idle movements since the cam lobe radii are known. The sum of these hundredths is calculated:

$$K_i=1+2.5+3+0.5+4+4+4.5+3=22.5 \text{ hundredths.}$$

Therefore, the number of hundredths required for working travel (after deducting overlapped motions) will be:

$$K_w=100-K_i=100-22.5=77.5 \text{ hundredths;}$$

$$n_{cycle}=\frac{n_w 100}{100-K_i}=\frac{2{,}217\times 100}{77.5}=2{,}861 \text{ revolutions.}$$

The hundredths on the cam for each operation element are determined on the basis of the number of spindle revolutions to each hundredth.

The number of hundredths for each operation element is determined from the formula:

$$K_o=\frac{n_o}{n_h} \text{ hundredths}$$

in which n_o is the number of spindle revolutions required for a given operation element (on the basis of the equivalent revolutions factor);

n_h is the number of spindle revolutions per hundredth.

The hundredths for the working travel will be:

$$K_{o_3}=\frac{450}{28.6}\approx 15.5 \text{ hundredths}$$

$$K_{o_5}=\frac{207}{28.6}\approx 7.5 \text{ hundredths}$$

$$K_{o_8}=\frac{230}{28.6}\approx 8 \text{ hundredths}$$

$$K_{o_{10}}=\frac{200}{28.6}\approx 7 \text{ hundredths}$$

$$K_{o_{11}}=\frac{200}{28.6}\approx 7 \text{ hundredths}$$

$$K_{o_{13}}=\frac{60}{28.6}\approx 2 \text{ hundredths}$$

$$K_{o_{14}}=\frac{60}{28.6}\approx 2 \text{ hundredths}$$

$$K_{o_{16a}}=\frac{180}{28.6}\approx (6.5) \text{ hundredths}$$

$$K_{o_{16}}=\frac{810}{28.6}\approx 28.5 \text{ hundredths}$$

$$K_{o_{16b}}=\frac{120}{28.6}\approx (4.5) \text{ hundredths}$$

These values are checked by adding up all the hundredths for working travel and deducting overlapped motions. The sum K_w should equal 77.5 hundredths. The hundredths are divided into those which are overlapped and those which are not. After deducting the overlapped hundredths, the remainder, in the sequence of the tooling layout, will indicate at which hundredth each motion will start and finish.

Determining the cycle time and change gear selection. The time in seconds to make one piece, which is equal to the cycle time T_c, is also equal to the time for one revolution of the camshaft:

$$T_c = \frac{60 \times n_{cycle}}{n_s^b} = \frac{60 \times 2,861}{1,050} \approx 164 \text{ sec.}$$

This time is finalised from the table in the service manual giving the available time in seconds per camshaft revolution: $T_c = 163$ sec. This corresponds to the change gears: $A = 20$, $B = 80$, $C = 60$, and $D = 45$ teeth.

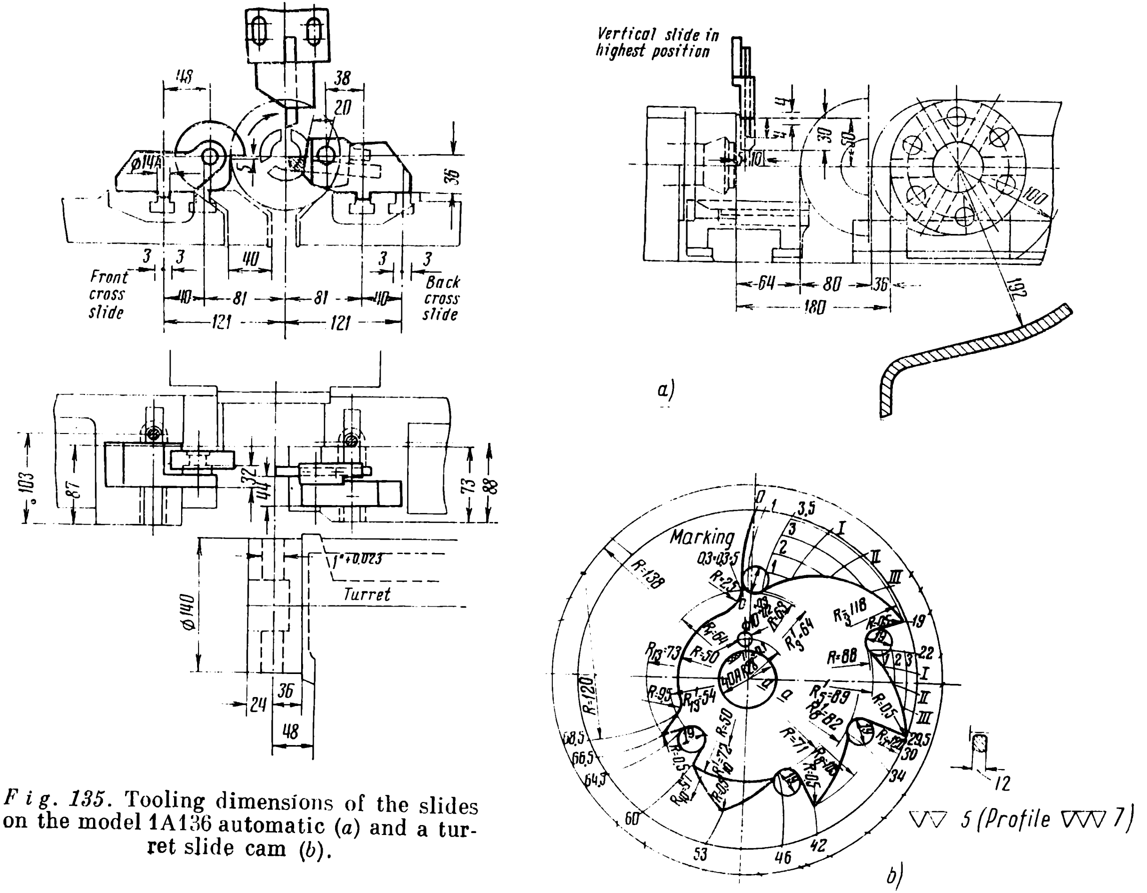
The rate of production is expressed as the number of pieces made per hour and is calculated by the formula:

$$Q_a' = \frac{3,600}{T_c} \eta = \frac{3,600}{164} \times 0.87 \approx 19 \text{ pcs/hr.}$$

Laying out the cams. The cams for the turret slide and front, back and vertical cross slides are layed out in accordance with the data of the operation sheet. The turret cam for the setup of Table 19 is shown in Fig. 135. The methods employed to lay out the lobes of this cam are also indicated. After manufacturing the cams and other special toolin g, the automatic screw machine can be set up and adjusted fors the job in hand.

First the pindle speeds are set up. For this purpose, the double cluster gear in the two-shaft gearbox is shifted to the position for the given range of speeds. Change gears, selected from the service manual, are to be installed on older models. Besides shifting the double cluster gear, on newer models, six trip dogs are installed. Each operates one of the limit switches LS1.

The camshaft drive gears (*A*, *B*, *C*, and *D*) are selected to suit the number of seconds to make one piece and are installed as shown in Figs. 125 and 128. Doors and covers must be closed after installing the gears. A spring collet, feeding finger and collar are installed of a size to suit the bar stock. The spring collet is changed by unscrewing the nut with L. H. thread on the spindle nose (see Fig. 126), removing the collet and then installing the new collet. Then the nut is replaced and is drawn up tight. The feeding finger is changed by removing the feeding tube together with the ball bearing, after releasing the screw which draws up the split section of the feeding slide housing. The feeding finger *4* is screwed on the tube end on L. H.



F i g. 135. Tooling dimensions of the slides on the model 1A136 automatic (*a*) and a turret slide cam (*b*).

thread. The nut is removed from the left end of the tube to change the stock collar. After this, the feeding tube with the new feeding finger is reinserted into the spindle and the split section of the feeding slide housing is drawn up tightly.

The clamping force provided by the spring collet is checked by chucking a bar and attempting to shift the chucking sleeve by hand with a lever. The clamping force is regulated with two nuts at the left end of the sleeve. When the collet is open, the bar should pass through it freely; the closed collet grips the bar firmly. In setting up, the stock feeding cam is adjusted so that stock feed begins only after the cut-off tool is fully withdrawn.

The chucking lever must be removed after setting up, otherwise it may cause an accident.

The device for adjusting stock feed (see Fig. 126) is set to feed a length equal to the workpiece length plus 4 or 5 mm. By turning the square head of the screw, the slide block may be adjusted to the required tube movement.

Stock is inserted either by hand or with the device shown in Fig. 134. Before insertion, a new bar should be carefully straightened, wiped off and oiled. After removing the butt end of the old bar from the spindle, the chucking lever is put on, the stock stop is retracted and the bar is pushed forward by hand so that 2 or 3 mm are cut off for squaring the end. Then the stock stop is returned to the working position and stock is fed by rotating the camshaft by hand. The stock stop is adjusted to its final position at this time.

The next setting-up operation is installing the turret and cross slide cams.

The turret cam *13* is mounted on the transverse section *15* of the camshaft (see Fig. 128). First the nut *12* is removed. The position of the cam on the shaft is determined by the hole for the locating pin. Since this hole coincides with the 0 hundredth and the lobes of all the cams are layed out on this principle, a strict sequence of movement and interaction is always provided for.

The cams for the cross slides are changed by removing the nuts on both parts of the camshaft, removing the cams and the claw clutches, and replacing the cams. In installing the cross slide cams, their lobes must be shifted in reference to the zero marks on the claw clutches by the number of hundredths indicated in the setup chart.

The next operation is to clamp and adjust the cutting tools. First the cut-off tool is set up. The distance from its left-hand edge and the chuck face must coincide with the dimension given in the setup chart. The cut-off tool is set so that in its extreme forward position it passes slightly beyond the work axis (0.3 to 0.5 mm). The roll of the lever actuating the slide must be on the highest point of the cam at this time. The stock stop may be finally adjusted only after the cut-off tool is properly set up.

Before making final adjustments on the other tools, it is necessary to set the trip dogs on drums *18* and *20* (see Fig. 128) to engage the single-revolution clutches of the auxiliary camshaft. Trip dogs for indexing the turret are mounted on drum *18*. At the end of the indexing movement, the roll of the segment gear lever, which operates the turret slide, should be at the beginning of the working feed lobe for the next operation element and at the end of the drop on the idle motion curve.

The cutting tools in the turret are finally adjusted after making the first test workpiece and carefully checking its dimensions to determine all the errors in comparison with the detail drawing.

Tools for machining external diameters are set to the lower limit of the tolerance; tools for machining holes are set to the upper limit.

Tooling dimensions and slide arrangement for model 1A136 are given in Fig. 135.

The machine is started on an automatic cycle only after final adjustments have been made in the cutting tools. Several test workpieces are then made and carefully inspected. If they conform to the specifications and the detail drawing, the machine is started for regular automatic operation.

CHAPTER III

SINGLE-SPINDLE SEMI-AUTOMATIC LATHES

§ 88. MACHINING SEQUENCE

A large number of different models of general- and special-purpose semi-automatic lathes, both the between-centres and chucking types, are produced in the Soviet Union (Tables 20 and 21).

Semi-automatics are multiple-tool machines designed for turning work of separate blanks (forgings or castings).

Blanks processed on semi-automatic lathes may differ greatly in form and size, therefore, the machines in this group may differ considerably in purpose, size, processing capacity, design, and general arrangement.

Single-spindle semi-automatic lathes may be classified as between-centres and chucking types.

The between-centres type of semi-automatic is used, as the name implies, for work held between centres. The work is usually of a length many times larger than the diameter.

The chucking type machines are employed for short work of large diameter.

It is, of course, evident that a chuck may be installed on between-centres machines to perform chucking work and that work may be held between centres on the chucking machines if a tailstock is installed.

Table 20

Brief Specifications of Multiple-Tool Semi-Automatic Lathes

Item	Unit	Model			
		45-1720	44-1730	116	118
Height of centres	mm	150	200	255	395
Maximum distance between centres	mm	300	500	450,800, 1200	600, 1000
Maximum diameter machined over slides	mm	200	335	200	450
Number of spindle speeds	—	12	12	8	9
Range of spindle speeds	rpm	105 to 1,000	40 to 500	56 to 376	19 to 126
Number of feeds	—	8	8	9	9
Range of longitudinal saddle feeds	mm/rev	0.7 to 1.02	0.12 to 1.38	0.26 to 1.89	0.19 to 2.74
Range across slide feeds	mm/rev	0.19 to 2.51	0.016 to 2.37	0.23 to 1.70	0.11 to 2.53
Motor power:					
main drive	kw	5.8	10	8-17	10-25.5
rapid traverse drive	kw	—	1	—	—
Overall dimensions:					
floor space occupied	mm	1,800× ×1,290	2,200× ×1,700	2,540× ×1,210	4,100× ×1,580
height	mm	1,340	1,420	1,820	2,400
Approximate net weight	kg	1,800	3,000	3,500	7,100

In the last years single-spindle semi-automatics are frequently furnished with magazine feed devices or automatic handling devices which convert them into fully automatic lathes.

Alternate tooling arrangements for turning work between centres are illustrated in Fig. 136.

Machining method No. 1. The complex stepped contour of the workpiece is machined by a single tool mounted in the front longitudinal slide. The movement of the slide duplicates a template. The tools in the rear slide turn faces and chamfers, and round off corners. Machining time is determined chiefly by the operation of the longitudinal tracer-controlled slide carriage which travels the full length of the workpiece.

Machining method No. 2. Five single-point tools are mounted on the front slide to machine the various steps. The middle tool duplicates the form of a template and turns the taper. Tools on the rear slide face the shoulders and chamfer, and round off the corners. The machining time is considerably shorter than in method No. 1 and is approximately equal to the time required to turn the taper.

Table 21

Brief Specifications of Single-Spindle Hydraulic Tracer-Controlled Semi-Automatics

Item	Unit	Model		
		1712	1722	1732
Maximum diameter machined	mm	125	200	310
Length of workpiece accommodated	mm	500	800	1,275
Range of spindle speeds . .	rpm	73 to 2,050	71 to 1,410	56 to 1,000
Maximum extension of the tailstock spindle	mm	130	175	200
Maximum total (working) travel of the tracer-controlled slide carriage:				
longitudinal travel . . .	mm	555/500	850/810	1,200/1,200
cross travel	mm	80/60	110/90	160/120
Maximum total (working) travel of the cross (facing) slide	mm	100/70	120/60	80/42
Range of feeds:				
tracer-controlled slide carriage	mm/min	20 to 700	20 to 700	7.5 to 500
cross (facing) slide . . .	mm/min	18 to 400	18 to 400	7.5 to 400
Speed of rapid traverse:				
tracer-controlled slide carriage (longitudinal and cross traverse)	m/min	5.5/1.0	3.5/1.3	2.7/1.7
cross (facing) slide . . .	m/min	2.3	2.0	2.4
Main drive motor power .	kw	10-14	14-28	40
Overall dimensions:				
floor space occupied . . .	mm	2,300× ×1,150	2,900× ×1,345	4,008× ×1,800
height	mm	1,900	2,100	2,100
Approximate net weight . .	kg	3,800	5,500	9,000

Note. Multiple-tool semi-automatics, models 1721 and 1731 differ slightly from models 1722 and 1732 in their chief specifications.

Machining method No. 3. The tools of the front slide turn the work without using any template whatsoever and, therefore, the taper is only rough turned. It is finished by the wide forming tool in the rear slide. Other tools in the rear slide face the shoulders and chamfer, and round off the corners. This method enables the taper to be turned by two tools, each travelling one half of its length. This decreases slide travel in comparison with method No. 2. The time required for the operation of the rear slide may increase somewhat since the use of the wide tool will demand a reduction in the rate of feed.

A comparison of these three methods shows that from the point of view of setting-up time, simplicity and low cost of tooling, the most expedient will be the sequence of operations shown in method No. 1. Tooling and setups of methods No. 2 and 3 are much more involved. The cycle time will be least for method No. 3 and slightly longer for method No. 2.

Tracer-controlled turning as illustrated in method No. 1 is more and more widely used, not only in lot but also in mass production. Stepped work is turned between centres or in a chuck on tracer-controlled lathes.

In selecting a machine tool for a job of this type, it is necessary to make a comparative analysis of multiple-tool and tracer-controlled machining. A general rule is that long workpieces may be turned more economically, in mass production, on multiple-tool semi-automatics, since the machining length is divided between many tools. Tracer-controlled semi-automatic lathes are more expedient for lot, and sometimes mass, production of comparatively short workpieces.

Comparative diagrams of calculated machining time for processing a stepped shaft on various types of single-spindle semi-automatics and automatics, in accordance with the lot size, are shown in Fig. 137.

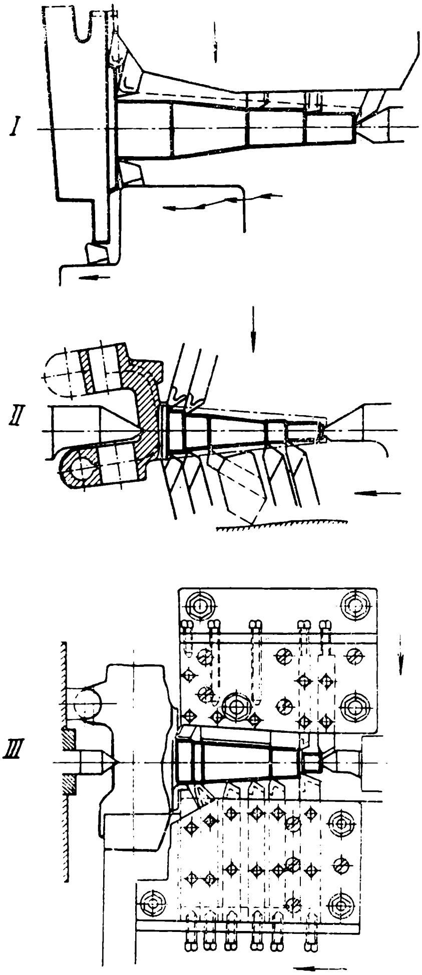
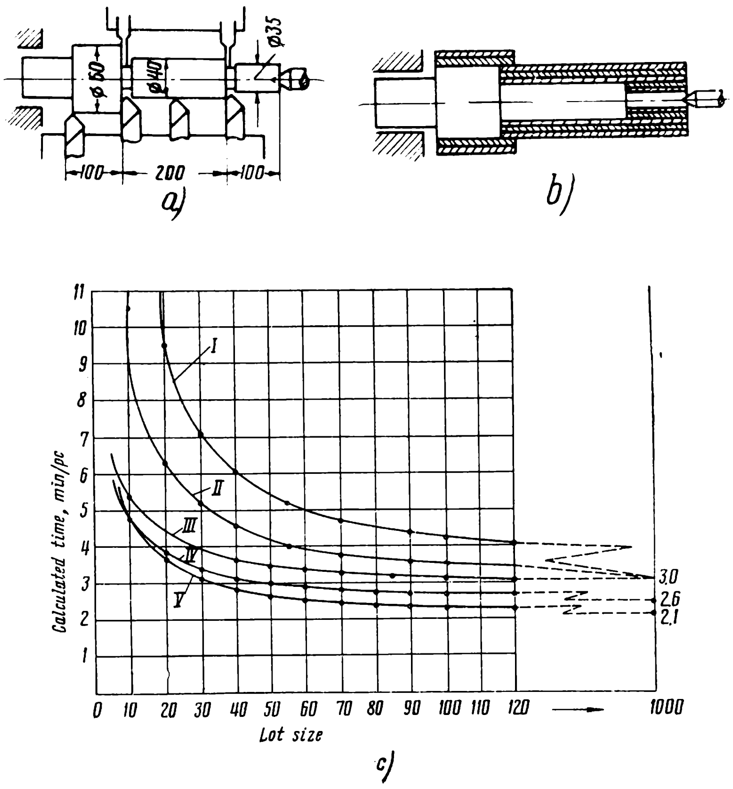


Fig. 136. Various machining methods for between-centres semi-automatics.

Fig. 138 illustrates typical tooling layouts for single-spindle semi-automatics. Comparatively long workpieces must be supported by the tailstock centre as in Fig. 138 *a*.

If the length of the work exceeds 15 diameters, a steadyrest must be used (Fig. 138 *b*). If the workpiece has a central hole and the ends are to be faced, it is mounted on an expansion mandrel. Mandrels may also be expediently employed in cases when the external surfaces must be concentric with previously machined bores (Fig. 138 *c*).



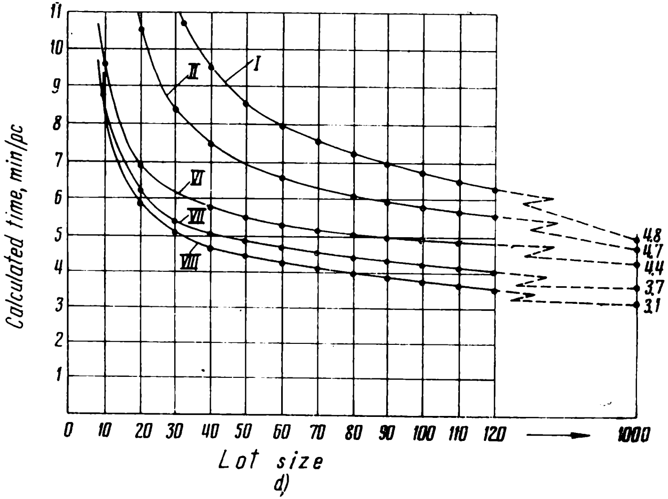


Fig. 137. Comparative diagrams of calculated machining time for turning a stepped shaft on different types of single-spindle lathes.

a — tooling layout, *b* — consecutive cuts, *c* — rough turning: *I* — on a mechanical-feed multiple-tool semi-automatic, *II* — on a hydraulic-feed multiple-tool semi-automatic, *III* — on a hydraulic tracer-controlled semi-automatic, *IV* — on a hydraulic tracer-controlled semi-automatic with infinitely variable automatic speed and feed changes, *V* — on a hydraulic tracer-controlled automatic with infinitely variable automatic speed and feed changes; *d* — rough and finish turning: *I* — on a mechanical-feed multiple-tool semi-automatic, *II* — on a hydraulic-feed multiple-tool semi-automatic, *VI* — on a multiple-cut hydraulic tracer-controlled semi-automatic, *VII* — same as *VI* but with infinitely variable automatic speed and feed changes, *VIII* — same as *VII* but on an automatic instead of a semi-automatic.

Tooling layouts, with the work held in a chuck, are illustrated in Fig. 138 *d* and *e*.

External surfaces may be machined with cross, longitudinal, or combined tool travel. Combined travel comprises two motions: feeding in to the required depth of cut and longitudinal feed. Machining long surfaces with cross feed-in is the most effective method since the machining length is "broken up" between the longitudinal-feeding tools and slide travel will be at a minimum. Factors limiting the use of this method may be lack of rigidity of the workpiece and the width of the surface to be machined.

Turning with cross feed is applied only for comparatively narrow surfaces. If stepped work is turned with a wide forming tool, the various steps will be machined consecutively. First, the smallest diameter on the work will be turned, etc. This is true if the blank is of cylindrical form. If the blank, a forging or a casting, has a stepped form, then turning may begin almost simultaneously on all the steps.

Turning with longitudinal feed and with several tools, each taking a consecutive cut, involves longer slide travel than cross turning does; the total chip cross-section increases in the course of operation and reaches a maximum value when the last tool starts its cut.

A large number of tools may work at the same time when external surfaces are turned by the combined method. Machining time is substantially reduced. This method, however, involves the cutting of a large total chip cross-section and requires lathes powered for heavy cuts. Slide travel may be reduced to minimum values. Limiting factors are the possibility of arranging the tools, lack of rigidity of the workpiece, and the available power of the lathe. In this type of setup, the travel equals the distance between adjacent tools.

Short work, which requires internal in addition to external machining, is best held in a chuck.

Copying or duplicating lathes with a tracer-controlled drive are being more and more widely applied. Their advantageous feature is that they turn stepped surfaces with one single-point tool that is easy to set up and easy to change. High-cutting speeds may be employed on these semi-automatics. This compensates for the losses due to longer travel than on multiple-tool machines. An example of a tracer-controlled turning setup is illustrated in Fig. 139.

§ 89. SINGLE-SPINDLE SEMI-AUTOMATIC LATHES WITH CAMSHAFTS AND CAM FEED DEVICES

Multiple tool semi-automatics with camshafts are widely used in the U.S.S.R. and in other countries. These machines have a high production capacity. Changing over from one job to another, however, takes considerable time, as do setting up and adjustments.

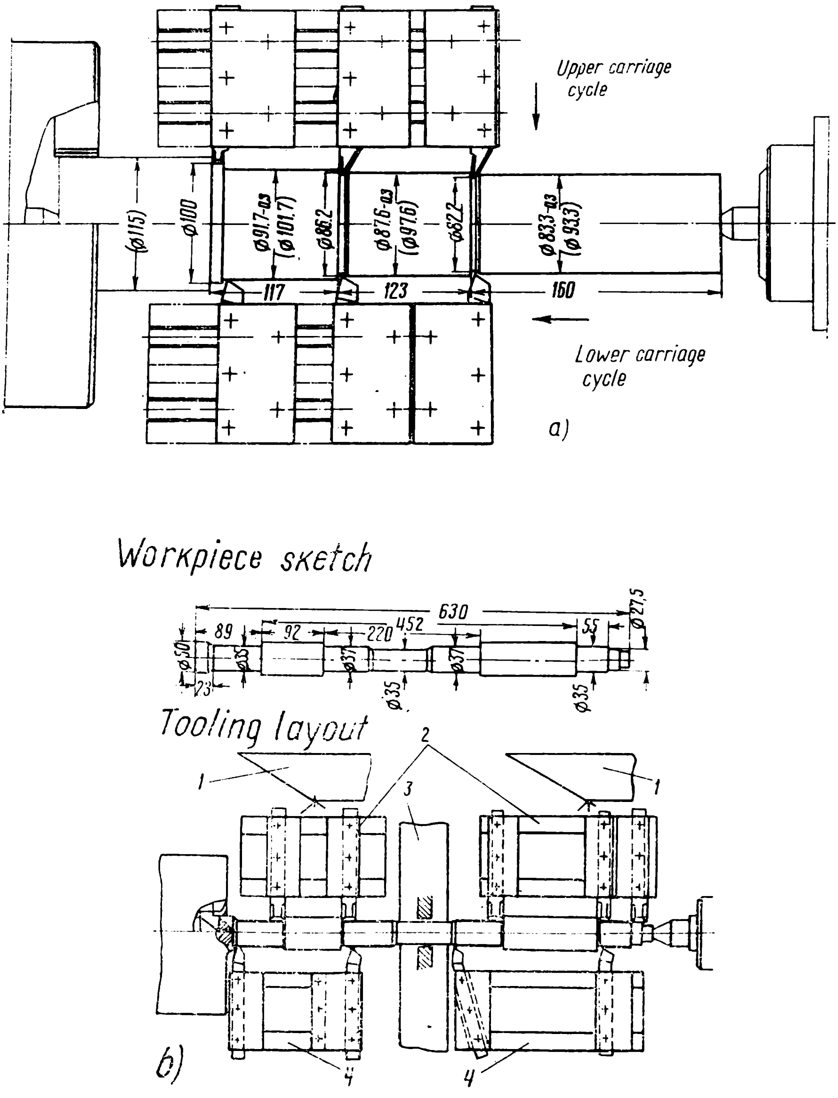
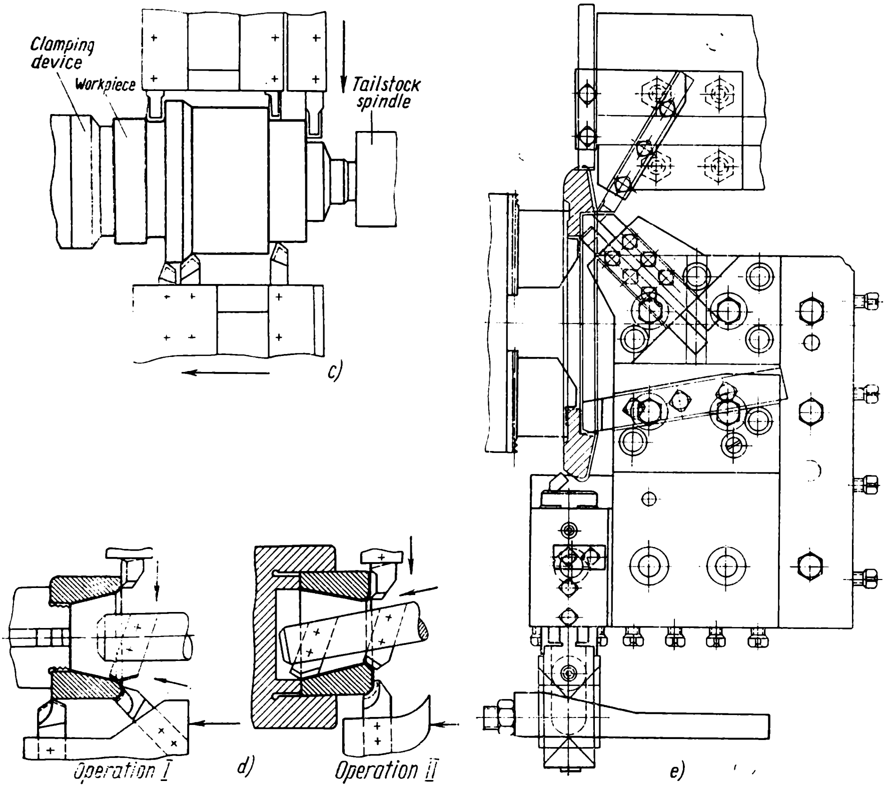


Fig. 138. Turning **work** on
a—work supported by tailstock centre, *b*—long workpiece supported by a steadyrest:
a mandrel, *d*—ring-shaped work held in a chuck,



multiple-tool semi-automatics.

1—cam bars, 2 and 4—toolslides, 3—steadyrest, c—hollow workpiece mounted on e — bevel gear blank held in a chuck.

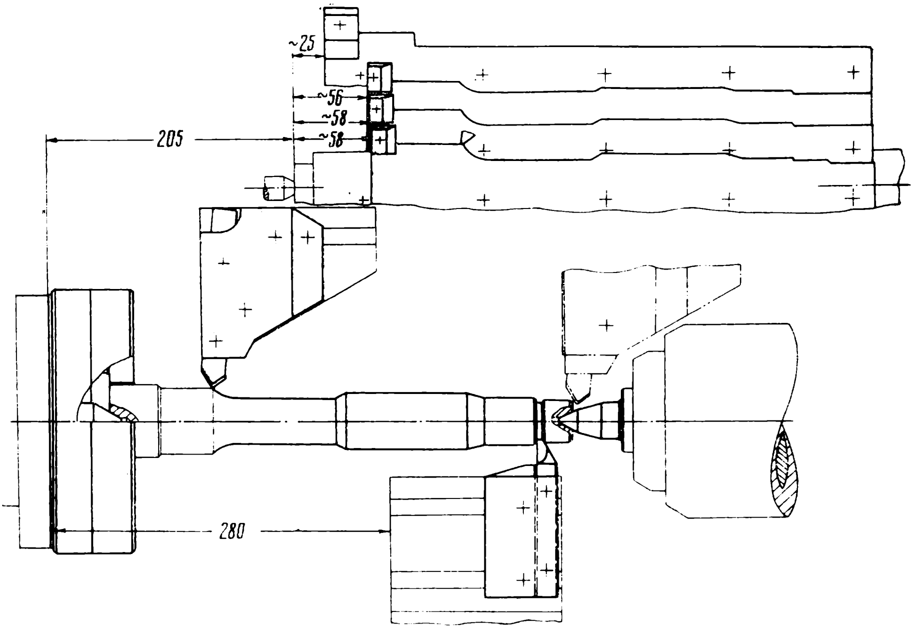


Fig. 139. Turning work on tracer-controlled lathes with automatic multiple-cut arrangements.

These lathes, in which automaticity is provided on a mechanical basis, by cam action, are described in the following paragraphs.

§ 90. MULTIPLE-TOOL SEMI-AUTOMATIC LATHE, MODEL 116

This semi-automatic (Fig. 140) is of a horizontal design in which the headstock, tailstock, carriage, and back arms are mounted on the bed.

All automatic movements of the operative units are obtained from cams on the camshaft arranged inside the bed.

As is evident from the gearing diagram (Fig. 141), the camshaft rotates at two speeds in each cycle: a high speed for idle motions and a slow setup speed for working travel. Three cam drums on the camshaft control all cycle elements through levers and tie-rods. The friction clutch and brake of the spindle drive are interlocked and may be operated both automatically and manually. The tailstock may be adjusted along the bed and clamped to suit the workpiece length.

The figures in Fig. 141 indicate the number of teeth on the gears.

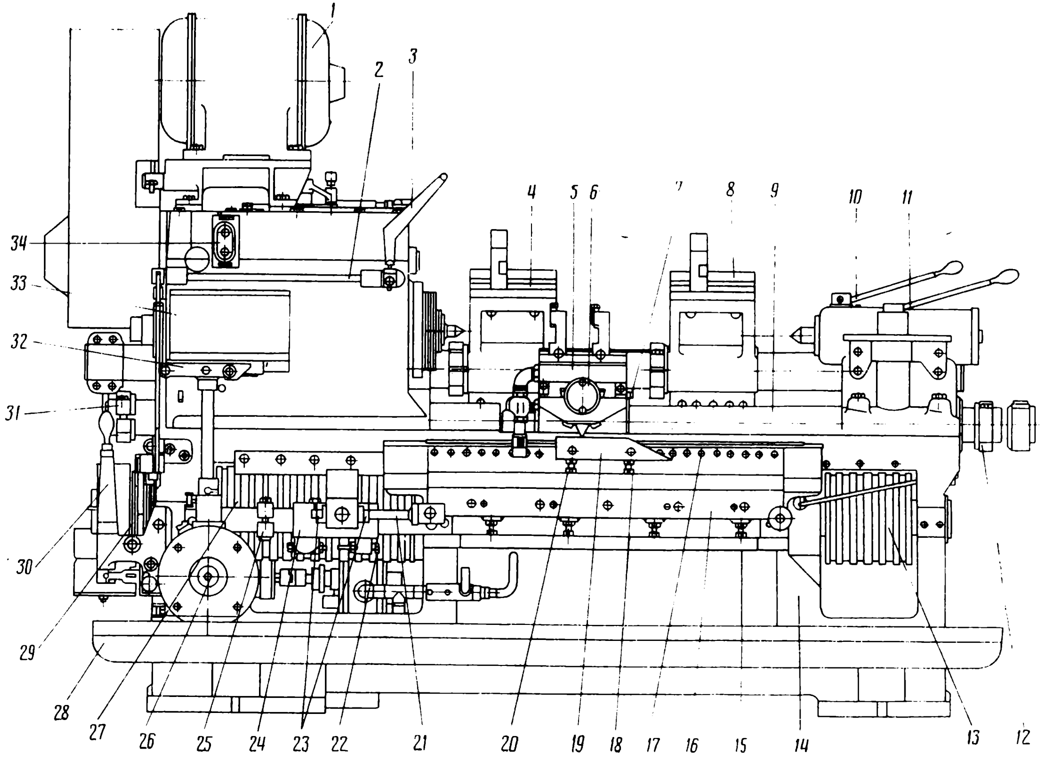
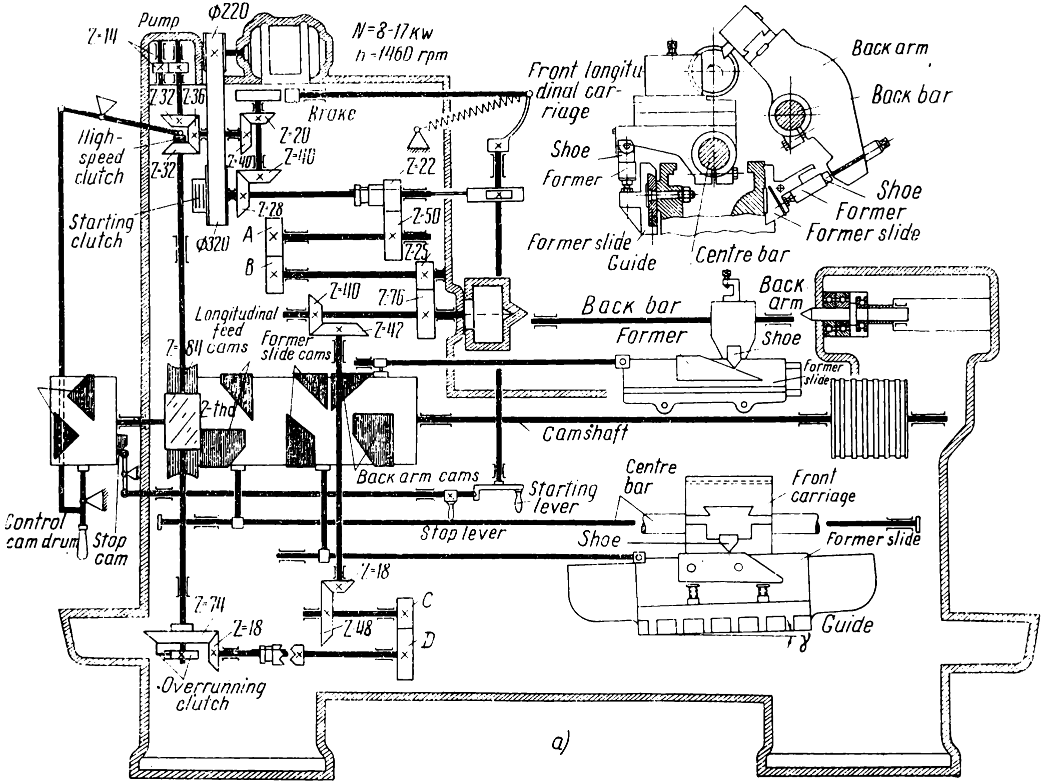


Fig. 140. Semi-automatic lathe, model 116.

1 — main drive motor, *2* and *3* — levers for manual control of the friction clutch and brake in the main drive, *4* and *8*—back arms, *6* — handwheel for setting the slide of the front carriage *5*, *7*—screws for clamping the sliding block of carriage *5*, *9* — centre (front carriage) bar, *10* and *11* — levers for extending and clamping the tailstock spindle, *12* and *31* — stop collars for limiting longitudinal travel, *13*, *27*, and *29* — cam drums, *14*—bed, *15*—jack screws for setting the former slide *16*, *17*—holes in the former slide for attaching former *19* with screws *18*, *20* — screws for setting the former, *19*, *21*, and *23*—nuts and tie-rods for adjusting the former slide, *22* and *25* — collars for limiting former slide travel, *24* — roll carrier, *26*—square shank for rotating the camshaft, *28* — chip pan, *30* — manual control lever, *32* — lever for starting the cycle, *33*—feed change gearbox, *34*—push button station.


Z=114
Pump
Φ220
N=8-17 kW
n=1460 rpm
Z 32
Z 36
Brake
Front longitudinal carriage
High-speed clutch
Z=32
Z=20
Z=40
Z=40
Z=22
Starting clutch
Z=28
Z=50
Φ320
A
B
Z=25
Z=110
Z=76
Longitudinal feed cams
Z=42
Z=84
Former slide cams
2-thd
Camshaft
Back arm cams
Starting lever
Control cam drum
Stop cam
Stop lever
Z=18
Z=74
Z=18
Z=48
C
D
Overrunning clutch
Back arm
Back bar
Shoe
Former
Former slide
Centre bar
Guide
Shoe
Former
Former slide
Back bar
Back arm
Former
Shoe
Former slide
Centre bar
Front carriage
Shoe
Former slide
Guide
a)

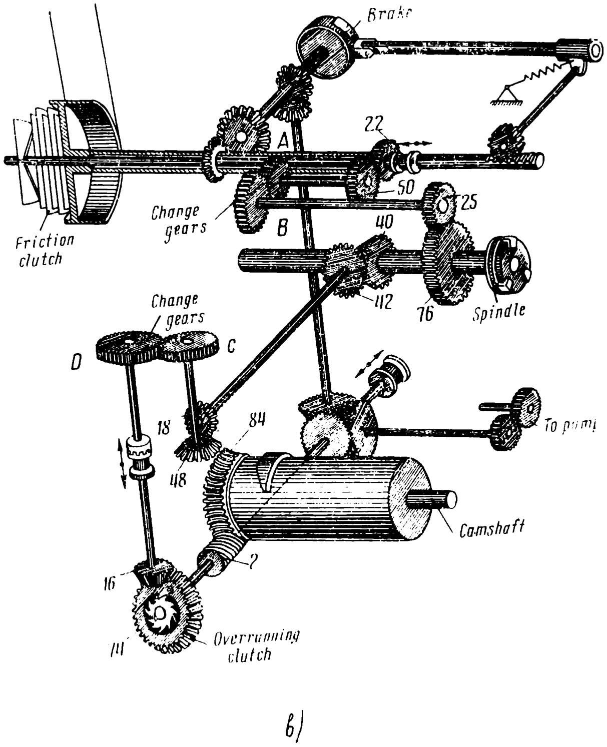


Fig. 141. Semi-automatic, model 116.

a – line gearing diagram, *b* – isometric-gearing diagram.

$$n_s = 1{,}460\,\frac{220}{320}\times\frac{22}{50}\times\frac{A}{B}\times\frac{25}{76}\ \text{rpm};\ A+B=72\ \text{teeth}.$$

$$n^w_{cs} = \frac{40}{42}\times\frac{18}{48}\times\frac{C}{D}\times\frac{18}{74}\times\frac{2}{84}\ \text{rpm};\ C+D=74\ \text{teeth}.$$

$$n^i_{cs} = 1{,}460\,\frac{220}{320}\times\frac{28}{40}\times\frac{20}{40}\times\frac{36}{32}\times\frac{2}{84}\ \text{rpm},$$

$$s_l = \frac{40}{42}\times\frac{18}{48}\times\frac{C}{D}\times\frac{18}{74}\times\frac{2}{84}\times\pi D\tan\beta_1\ \text{mm/rev},$$

in which $D=255$ mm and β_1 is the cam rise angle

$$s_c = \frac{40}{42}\times\frac{18}{48}\times\frac{C}{D}\times\frac{18}{74}\times\frac{2}{84}\times\pi D\tan\beta_2\ \text{mm/rev},$$

in which $\beta_2 = 26°$.

$$T_c = \frac{\alpha}{360}\times\frac{1}{n^w_{cs}} + \frac{360-\alpha}{360}\times\frac{1}{n^i_{cs}}$$

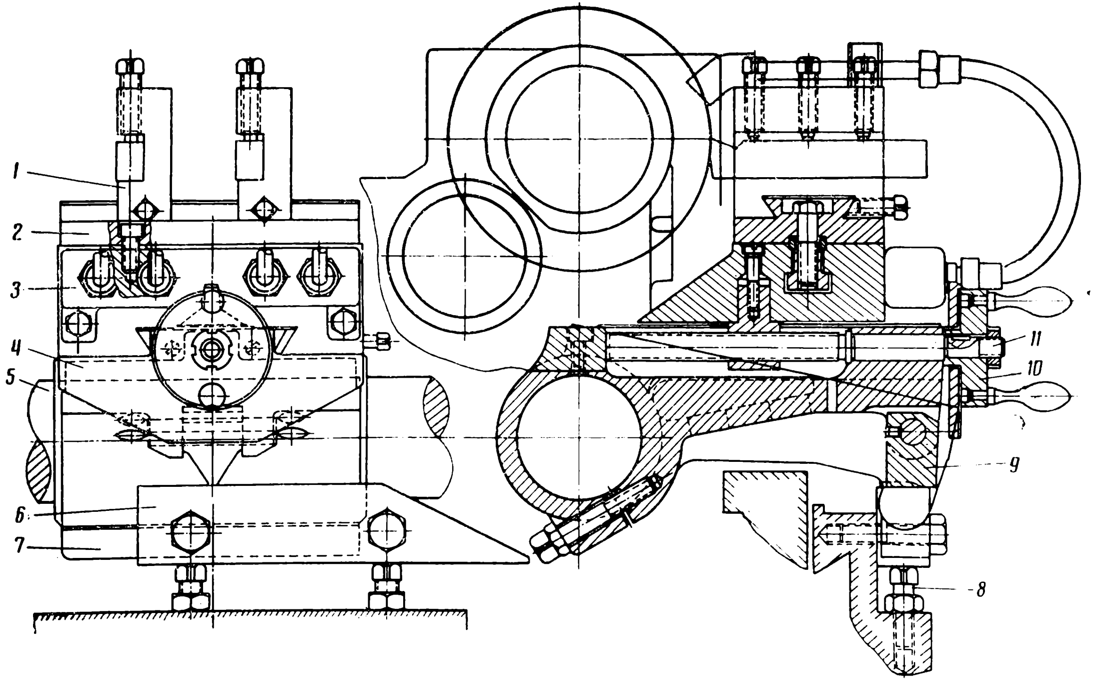


Fig. 142. Carriage of semi-automatic, model 116.

1 — tool block, *2* — dovetail slide, *3* — sliding block, *4* — carriage body, *5* — centre bar, *6* — former, *7* — former slide, *8* — screw for adjusting former *6*, *9* — toe on carriage shoe, *10* — handle of screw *11* for cross settings of sliding block.

The carriage and back arms are of the tilting type, i. e., crosswise movement of the tools is due to a rocking motion actuated by cams. The front longitudinal carriage comprises three parts (Fig. 142): the carriage body *4*, sliding block *3*, and dovetail slide *2*, to which the tool block or holder *1* is fastened on a dovetail. The body *4* has the form of a bracket clamped on the centre bar *5* which travels together with the carriage and is operated from cams on the drum. A shoe with a follower toe *9* is hinged to the overhanging part of the carriage body. This toe slides along a flat cam *6*, called a former, mounted on the former slide *7* and adjusted by levelling screws *8*. The former slide has a longitudinal motion controlled from a cam on a drum. The former *6* causes the tools to move along an angular path to start the cut when the toe slides on the inclined surface of the former. The sliding block *3* on the body *4* may be adjusted in a cross direction by the screw *11* and handle *10* to obtain the required work diameter. Longitudinal movement of the carriage is actuated by single-edge cylinder cams followed by a roll carrier mounted on the centre bar *5* which carries the carriage body. Stop collars on the bar limit carriage travel.

The rear tool slide or back arm (Fig. 143) has a tilting motion only. The body *3* is a double-arm lever which rocks together with the back bar *4* on which it is mounted. The tool block *1* is mounted directly on its dovetail slide *2*. The back arm is adjusted to the workpiece diameter by the ram *6* which may be set by the screw *5* as required in the body *3*. The arm carries the shoe *7* with its toe.

The shoes of both carriage and back arm are held tightly against their formers by the action of weights through a system of levers.

A typical operating cycle for the model 116 semi-automatic is shown in Fig. 144. Here, in *position I* the carriage starts its rapid approach to the work, in *position II* the carriage feeds in to start the cut, in *position III* the carriage tools begin to turn the work and the back-arm approaches the work, in *position IV* both carriage and back arm have reached the end of their working feed, in *position V* the carriage is retracted slightly from the work to provide tool relief and then both carriage and back arm are returned, and in *position VI*, reach their initial positions.

The cams required for the operating cycle are mounted and fastened in the slots of the large drum. The cams are selected from the service manual to provide the required length of travel.

These semi-automatics are set up in the following order.

1) The chucking or clamping device is checked as well as the position of the tailstock. The spindle speed and cycle time are set up in accordance with the tooling layout and setup chart.

2) The working feed cams are installed; first the front carriage cam is mounted so that, before carriage return to the initial position, the former slide has a movement of 15 or 20 mm to provide for a slight

retraction of the tools from the machined surface. The cam for engaging slow travel of the camshaft is then installed as are the remaining cams.

3) All cams are set up tentatively at first and are finally clamped after inspecting the test workpiece and making all readjustments.

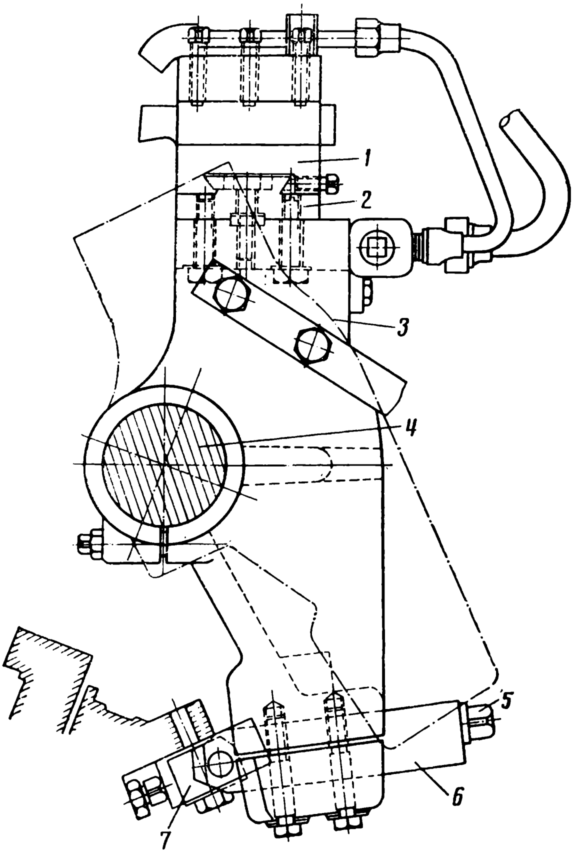


Fig. 143. Back arm of semi-automatic, model 116.
1 — tool block, 2 — dovetail slide, 3 — back arm body, 4 — back bar, 5 — screw for adjusting shoe and toe, 6 — ram, 7 — shoe.

4) Tools are clamped in the carriage tool blocks with the sliding block retracted. The master workpiece is mounted between centres or in the chuck. The camshaft should be in the position when the toe of the carriage is at the point just beyond the rise on the former of the former slide. By means of the adjusting screws, the tools are advanced to contact the master workpiece, then the former is clamped

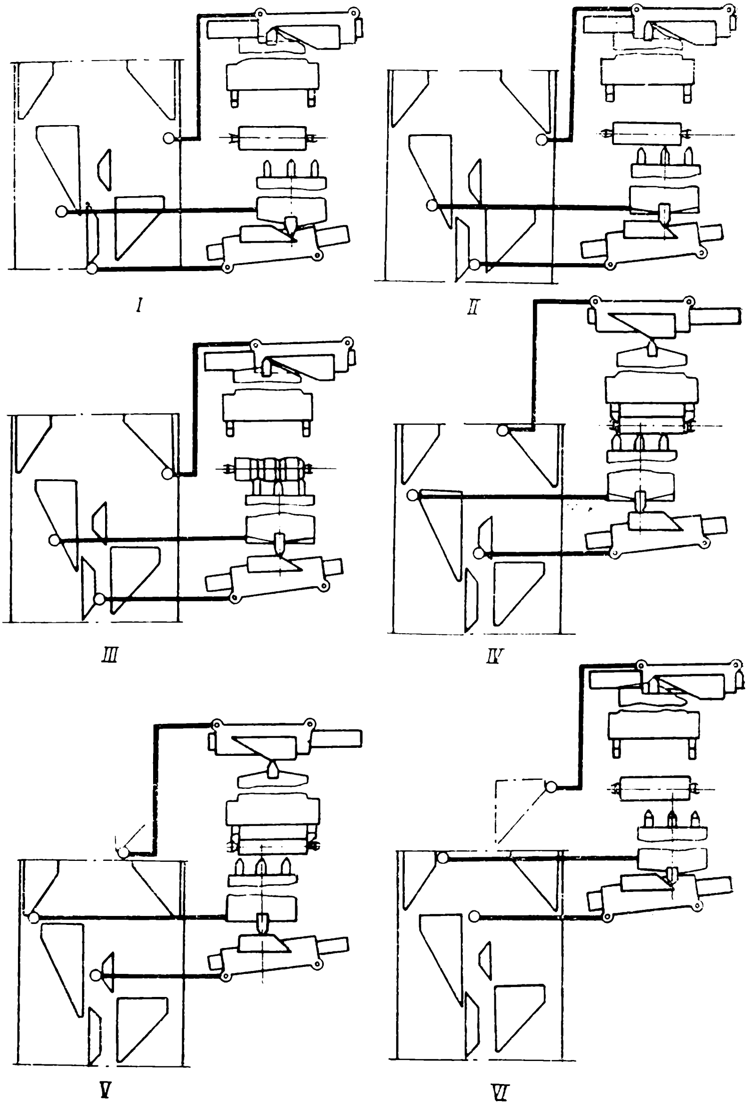


Fig. 144. Carriage operating cycle for semi-automatic, model 116.

tightly. The camshaft is then rotated further until the roll of the centre bar reaches the flat after the rise for longitudinal feed. At this, all the tools have reached the end of their travel, i. e., the end of their steps. If everything is in order, the tools and cams are clamped properly.

5) The back arm is set up with the counterweights removed. The final position at the end of tool travel is checked.

6) Test workpieces are turned and after inspection the tools are readjusted as required. Another test workpiece is turned with manual rotation of the camshaft. The design of semi-automatic, model 118, is very similar to that described above for model 116.

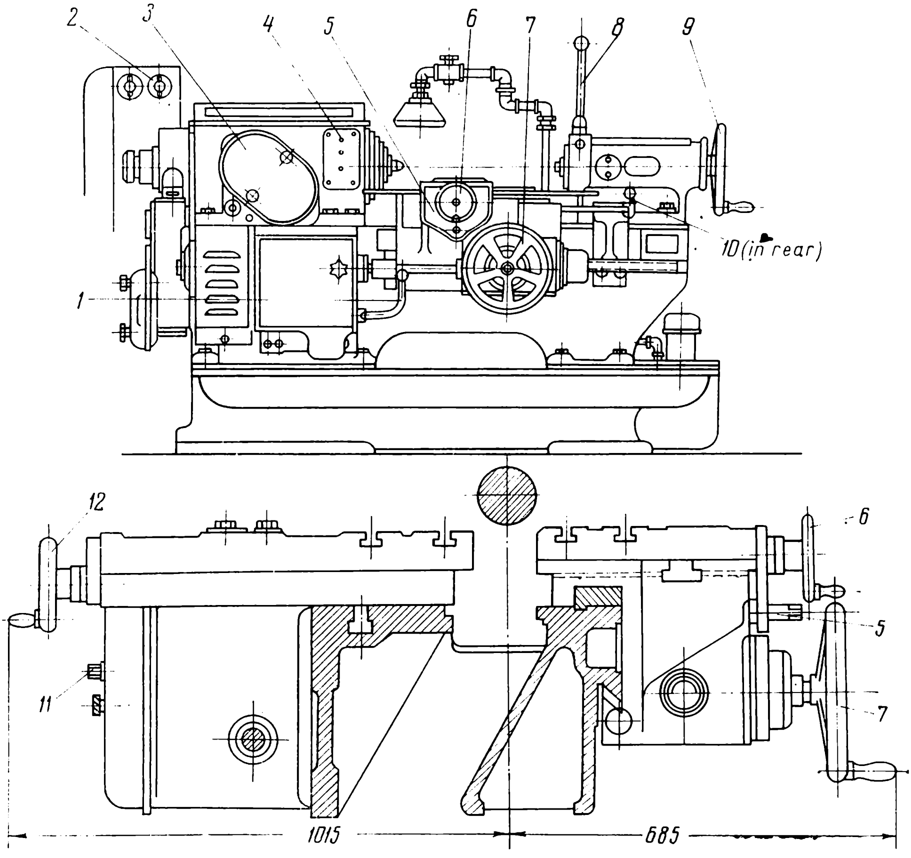


Fig. 145. Multiple-tool semi-automatic lathe, model 44-1730.

1—control lever, 2—pump switch, 3—main drive change gears, 4—push-button station, 5—square shank of removable handle for adjusting the front carriage spring, 6—handwheel for cross traverse of the front toolslide, 7—handwheel for longitudinal traverse of the front saddle, 8—tailstock spindle binding lever, 9—handwheel for extending the tailstock spindle, 10—adjusting screw for setting the tailstock, 11—square shank of removable handle for setting the rear carriage, 12—handwheel for cross traverse of the rear toolslide.

§ 91. MULTIPLE-TOOL SEMI-AUTOMATIC LATHES, MODEL 1720 AND 1730

These semi-automatics are general-purpose machines; their setting up does not involve the manufacture of special cams or even change-overs of the camming system. The general arrangement of the units of these machines (Fig. 145) differs only slightly from that of ordinary engine lathes. The longitudinal front carriage travels on the bed ways in the front of the lathe, the cross feeding carriage is arranged in the rear. Line and isometric gearing diagrams of the larger of these lathes, model 1730, are illustrated in Fig. 146 *a* and *b*. The figures in Fig. 146 *a* indicate the numbers of teeth on the gears.

A lead screw provides longitudinal feed of the front carriage; the feed is set up with change gears. A rack is fastened to the front carriage saddle. It drives the rear cross slide through gearing and a cylinder cam. Rapid slide traverse is powered by a separate motor through an overrunning clutch. Manual travel is accomplished by a handwheel with the claw clutch of the feed drive disengaged. The semi-automatic is controlled from a single lever and by an automatic electrical system. The operating cycle is set up with change gears and adjustable trip dogs.

The operating cycle consists of rapid approach, working feed, and rapid return of the tool slides to the initial position. At the end of the cycle, the spindle rotation is automatically switched off, the finished workpiece is unloaded by hand and a new blank is mounted.

Machine control is based on the in-travel or sequential principle. Therefore, setting-up consists mainly in setting trip dogs and stops of the rack in the automatic control system to the required length of longitudinal travel. The movement of the rack is one half of carriage travel.

Calculation of machining time for a given workpiece is based on the time required for front carriage travel since rear slide movement is obtained from this travel. Rapid approach and withdrawal is performed at a speed of 2.3 m per min.

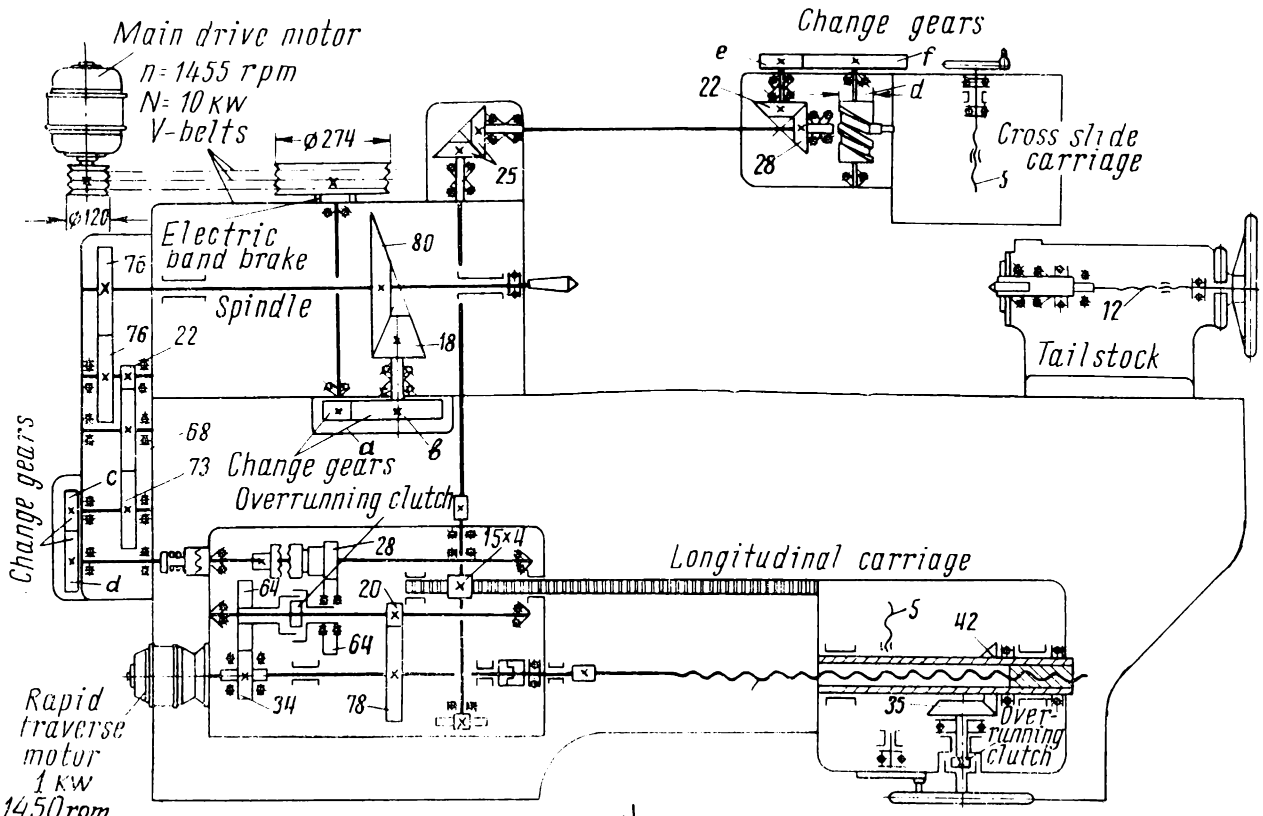
Example: Determine the cycle time for machining a workpiece on the semi-automatic, model 1730. Spindle speed $n_s=200$ rpm, full length of front carriage travel $L=150$ mm, which includes a working travel $l=60$ mm at a feed of $s=0.50$ mm per revolution.

Time required for the rapid approach movement will be:

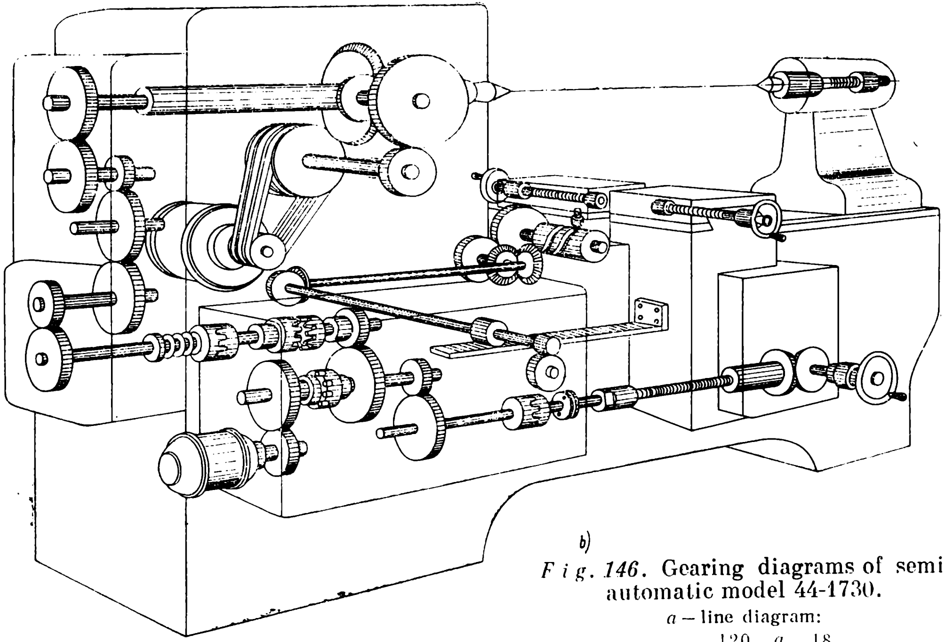
$$t_{ra}=\frac{(L-l)\,60}{2,300}\approx 2.4 \text{ sec.}$$

Time required for working feed will be:

$$t_w=\frac{60\times 60}{n_s\times s}=\frac{60\times 60}{200\times 0.5}=36 \text{ sec.}$$


Main drive motor
n = 1455 rpm
N = 10 kW
V-belts
ø274
ø120
Electric band brake
Spindle
80
18
76
76
22
68
73
c
d
Change gears
a
в
Change gears
25
Overrunning clutch
28
15×4
64
64
20
34
78
Rapid traverse motor 1 kW 1450 rpm
Change gears
e
f
22
28
d
Cross slide carriage
5
12
Tailstock
Longitudinal carriage
5
42
35
Over-running clutch

a)



F i g. *146*. Gearing diagrams of semi-automatic model 44-1730.

a – line diagram:

$$n_s = 1.455 \times \frac{120}{274} \times \frac{a}{b} \times \frac{18}{80} \text{ rpm}$$

$$s_l = \frac{76}{76} \times \frac{22}{68} \times \frac{68}{73} \times \frac{c}{d} \times \frac{28}{64} \times \frac{20}{78} \times 12 = 0.405 \frac{c}{d} \text{ mm/rev}$$

$$s_c = s_l = \frac{1}{3.14 \times 4.15} \times \frac{25}{25} \times \frac{28}{22} \times \frac{e}{f} \pi D \tan \beta = 0.485 \frac{e}{f} s_l \text{ mm/rev}$$

$$v_l^i = 1.425 \times \frac{34}{64} \times \frac{20}{78} \times 12 \times \frac{1}{1,000} \approx 2.3 \text{ m per min in which } \pi D \tan \beta = 72$$

v_l^i – is the rapid traverse speed in a longitudinal direction,

b – isometric diagram.

Time required for rapid return will be:

$$t_{rr}=\frac{150\times 60}{2,300}\approx 4 \text{ sec.}$$

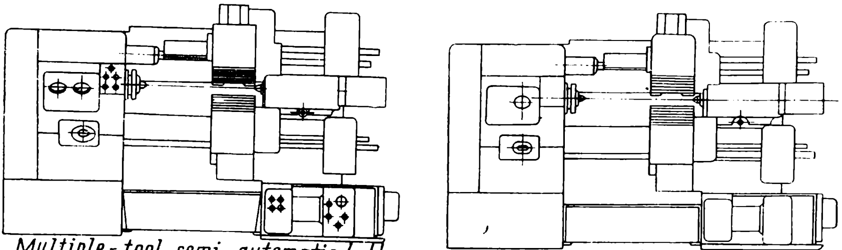
The total machining time will then be:

$$T_m=t_{ra}+t_w+t_{rr}=2.4+36+4=42,4 \text{ sec.}$$

If to this value is added the handling time required for starting the lathe, loading, clamping, and unloading the work, the result will be the cycle time.

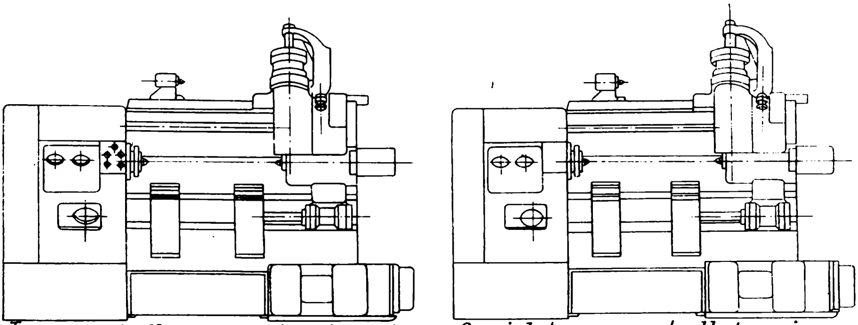
§ 92. HYDRAULIC SINGLE-SPINDLE SEMI-AUTOMATIC LATHES

Hydraulically-operated lathes possess considerable advantages in comparison with machines whose automaticity is based on camshafts and cam mechanisms. A hydraulic drive facilitates and simplifies automation. It substantially reduces the time required for setting-up operations and enables the capacity of the lathe to be more efficiently



Multiple-tool semi-automatic lathe (basic model) Model 1721

Special multiple-tool semi-automatic lathe Model 1721C



Tracer-controlled semi-automatic lathe Model 1722

Special tracer-controlled semi-automatic lathe Model 1722C

Fig. 147. Unified multiple-tool and tracer-controlled lathes, models 1721, 1722, 1721C, and 1722C.

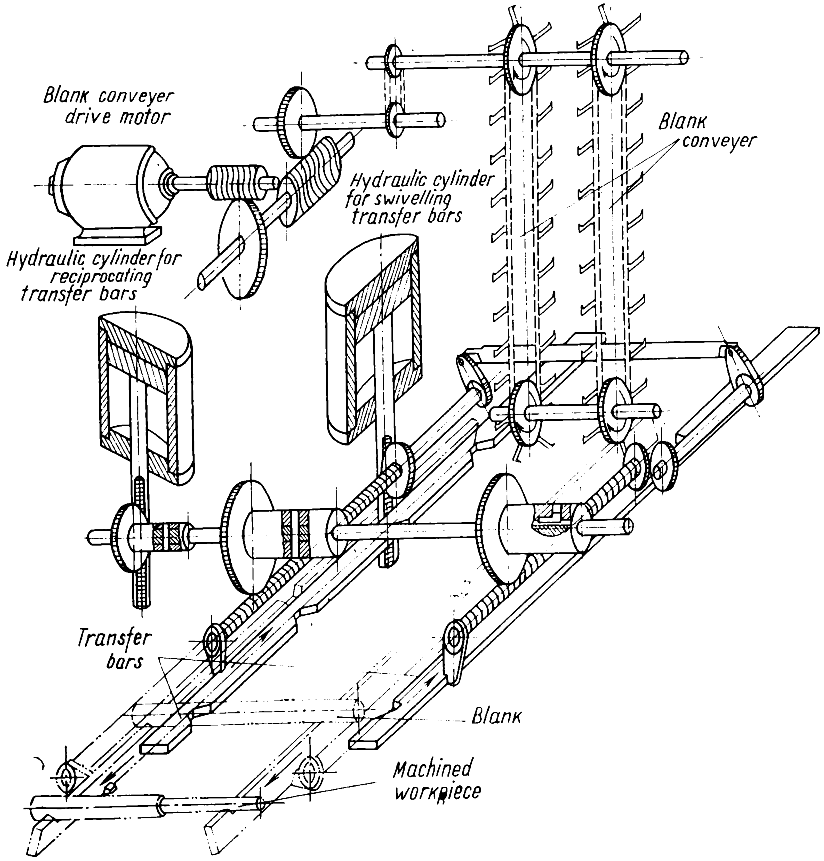

Blank conveyer drive motor
Blank conveyer
Hydraulic cylinder for swivelling transfer bars
Hydraulic cylinder for reciprocating transfer bars
Transfer bars
Blank
Machined workpiece

Fig. 148. Schematic diagram of a magazine-feed device for single-spindle lathes.

used. A large number of general-purpose, single-purpose and special lathes with hydraulic drives are manufactured in the Soviet Union. A range of hydraulically-operated lathes comprising several sizes of multiple-tool and tracer-controlled models are available (see Table 21). Semi-automatics in this range are high-speed, powerful, high-production lathes which may find effective application not only in mass, but in lot production as well.

Since the machines in this range are unified (Fig. 147) on the basis of a common basic model, only one multiple-tool and one tracer-controlled lathe will be described. All of these models may be equipped with magazine feeds (Fig. 148) and operate as fully automatic lathes.

§ 93. MULTIPLE-TOOL SEMI-AUTOMATIC LATHE, MODEL 1721

This semi-automatic lathe (Fig. 149) is designed for turning various types of shafts between centres, work mounted on a mandrel, etc. Work may also be held in a chuck.

The semi-automatic comprises the following principal units: bed, headstock with speed gearbox, tailstock, upper and lower carriages with their drives, hydraulic system with oil tank and control panels, and electrical equipment.

General arrangement. Model 1721 has a highly rigid frame-type bed mounted on legs. The right-hand leg contains the hydraulic oil tank; the left-hand leg houses the main drive motor. The ways for the upper and lower carriage are arranged in a single plane at an angle of 15° from the vertical. The headstock and the hydraulic cylinder for longitudinal feeds of the upper and lower carriages are mounted at the left-hand side of the bed. The tailstock is mounted at the right on special ways.

Recesses at the rear of the bed contain electrical devices and the hydraulic pump motor.

Headstock with speed gearbox (Fig. 150). The spindle is driven from the motor through V-belts and further through the speed gearbox. The spindle is stopped by a brake with electromagnetic controls. The spindle runs in antifriction bearings. The front support consists of

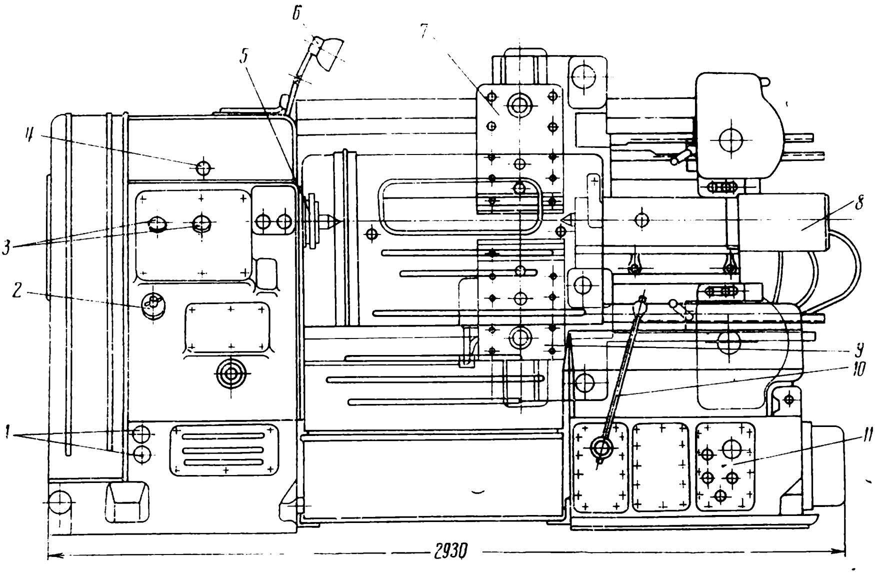


Fig. 149. Hydraulic multiple-tool semi-automatic lathe, model 1721.
1—cutting fluid cocks, *2*—handle for cleaning the filter, *3*—hexagonal shank for changing spindle speeds, *4*—setting up control panel, *5*—spindle, *6*—work light, *7*—upper carriage, *8*—tailstock, *9*—lower carriage, *10*—tailstock control lever, *11*—control panel.

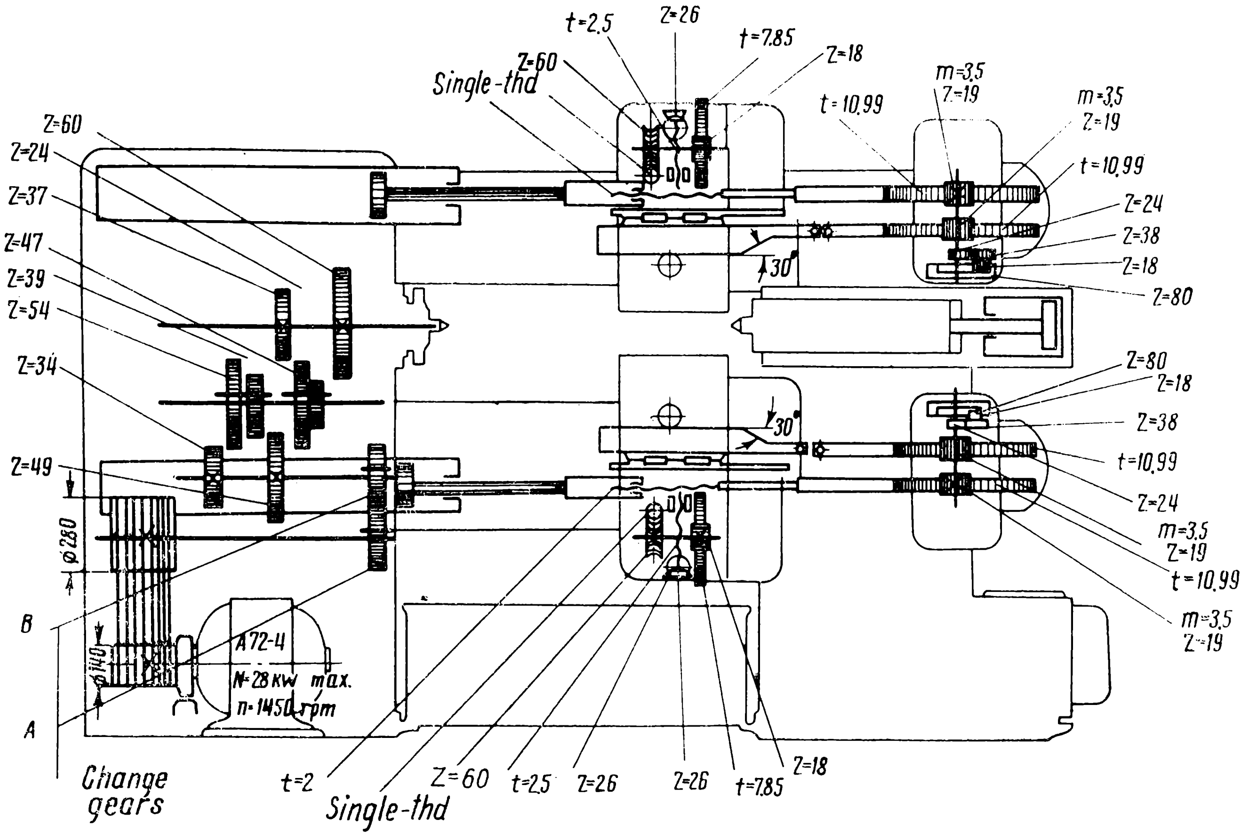
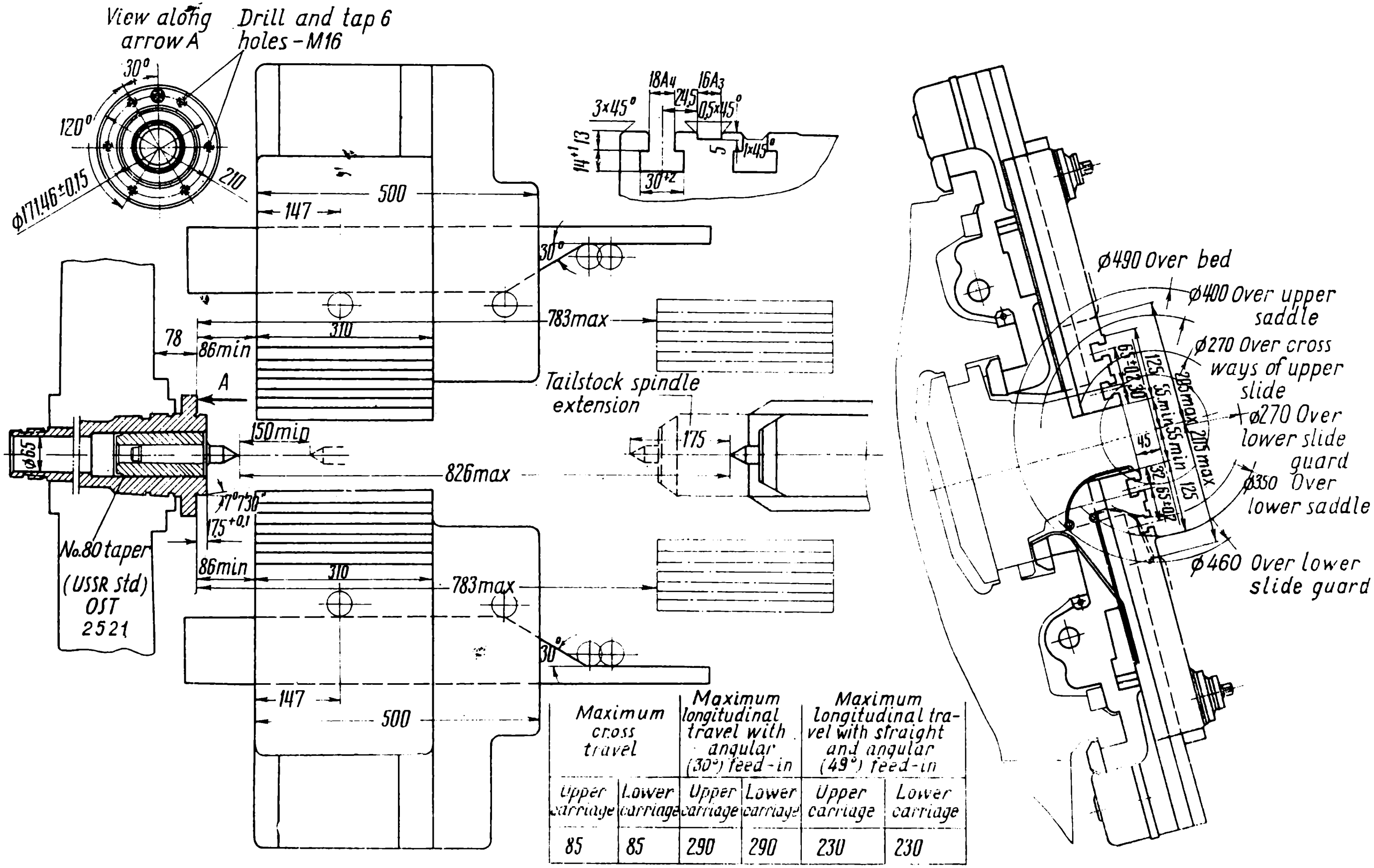


Fig. 150. Gearing diagram of the speed gearbox for the semi-automatic lathe, model 1721



Maximum cross travel		Maximum longitudinal travel with angular (30°) feed-in		Maximum longitudinal travel with straight and angular (49°) feed-in	
Upper carriage	Lower carriage	Upper carriage	Lower carriage	Upper carriage	Lower carriage
85	85	290	290	230	230

Fig. 151. Capacity chart and carriage arrangement for semi-automatic lathe, model 1721.

a cylindrical roller bearing with a tapered bore and two thrust bearings. The rear support consists of two ball bearings.

The front spindle support is adjusted by removing the headstock cover and by tightening or loosening the adjusting nuts as required.

The speed gearbox provides for spindle speeds in a range from 71 to 1,410 rpm by means of two sliding double cluster gears and change gears.

The speed gearbox is lubricated by an individual plunger pump which delivers oil to a central distributing bath inside the headstock. From here it flows to all gears and bearings.

The *tailstock* is clamped on special ways. This enables the carriages to be withdrawn to their extreme right-hand positions beyond the tailstock.

The tailstock spindle runs in antifriction bearings (see Fig. 80). Its front support consists of a cylindrical roller bearing and two ball thrust bearings; the rear support consists of two radial ball bearings.

The tailstock spindle is actuated by a hydraulic cylinder controlled by a lever on the oil tank. Two hydraulic cylinders in the tailstock housing clamp the spindle; when the tailstock centre bears against the workpiece oil enters these cylinders and binds the tailstock spindle.

The front support is adjusted by removing the stamped cover and rotating the nut after first unlocking it. If it is necessary to adjust the roller bearing to the left, the plug is removed from the tailstock spindle, the nut is secured and the spindle is turned.

The bearings of the inner tailstock spindle are grease-lubricated through fittings on the top of the tailstock.

Carriages. Each carriage is traversed by a hydraulic cylinder mounted on the left-hand side of the bed. By means of the cam bar saddle, the toolslide may operate with straight, angular, or combined feed-in, as well as with cross movement (Fig. 152).

In angular feed-in, the cam bar is rigidly attached to its saddle which is fastened to the bed with screws and a wedge.

Upon longitudinal travel of the carriage, the roller, linked to the toolslide, follows the inclined part of the cam to accomplish angular feed-in for starting the cut. When the roller reaches the horizontal section of the cam, the tools begin turning a cylindrical surface.

The tools are retracted from the work at the end of the cut by a retraction bar, arranged under the cam (Fig. 153). At the end of the working feed, the travelling retraction bar runs against a stop, secured to the bed; its projections are shifted from those of the stationary cam bar and the tools are relieved.

At the end of the return travel, the retraction bar runs against another stop which sets it up again for the next cycle.

Carriage travel in both directions is limited by these stops.

The cutting tools are set to the depth of cut by a square shank on the front of the cross slide (see Fig. 150). The carriage is lubricated by

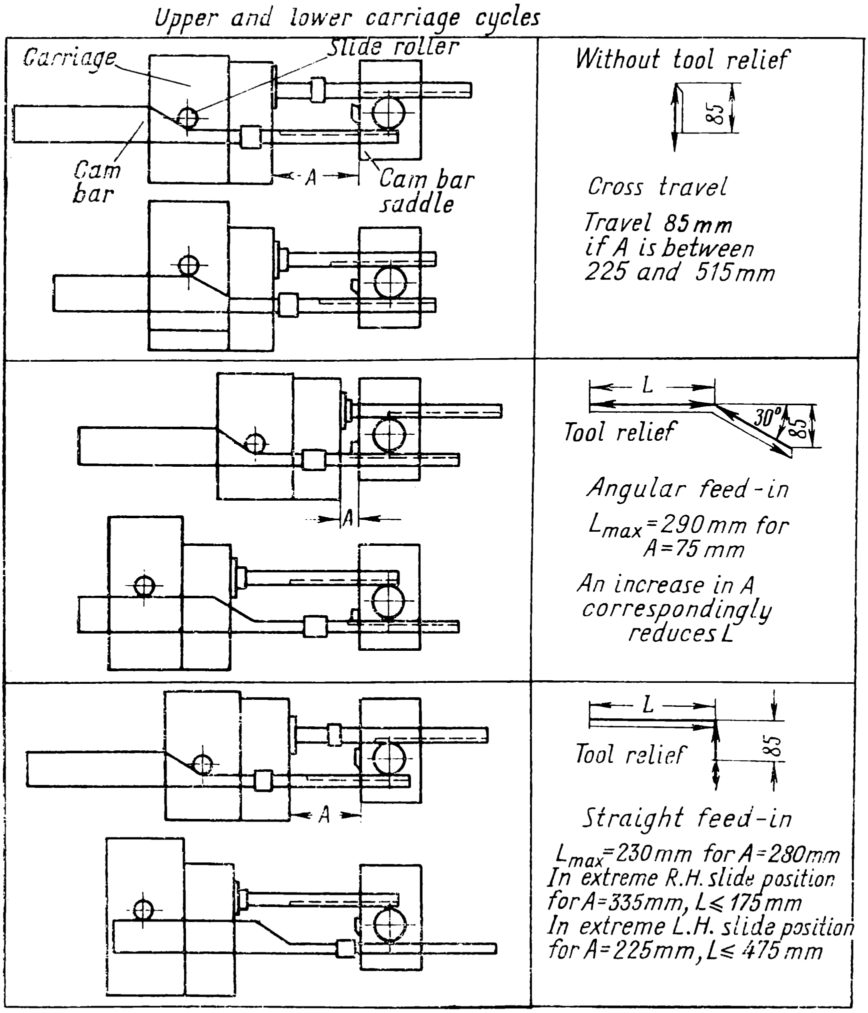


Fig. 152. Cycles of toolslide and carriage operation for the model 1721 semi-automatic lathe.

a lubricator. The cross slide is held tightly to the cam bar by a strong spiral spring. To replace this spring, it must be removed together with its case from the carriage housing. A new spring is installed only with its case.

Never remove the spring from its case in unconfined space as it may injure the operator in unwinding.

The design of the upper and lower carriages is such that each may be employed both for longitudinal and cross travel.

The drives of the cam bars in the upper and lower carriages are identical in design. In addition to their main functions, the cam bar saddles carry the carriage controls. These are actuated by trip dogs on a drum and limit switches which energise solenoids of the hydraulic control panels (Fig. 154).

Hydraulic control panels of the lower and upper carriages and the tailstock are arranged in the walls of the right-hand leg of the bed. The motor driving the tandem vane pump of the hydraulic system is mounted on the oil tank.

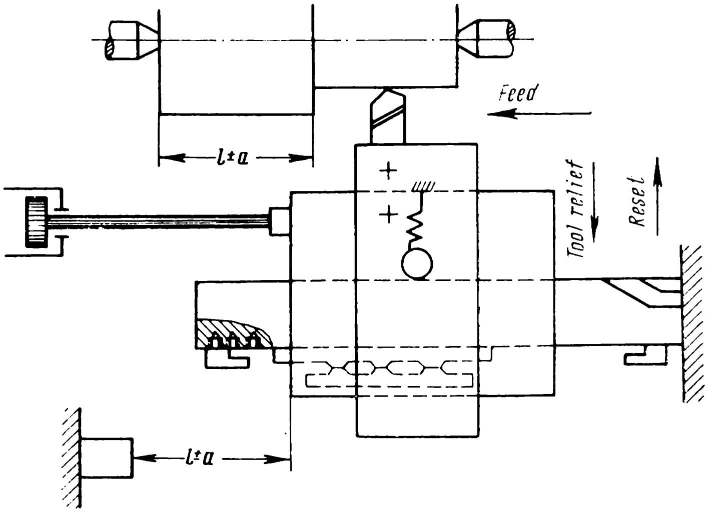


Fig. 153. Operation of a tool relief mechanism on toolslides of semi-automatics.

Coolant system. The chip pan is of welded construction and is designed to catch chips and soluble oil cutting fluid.

The pan is arranged between the legs and is connected by a pipe to a compartment of the left leg which houses the electric coolant pump.

Hydraulic system. The hydraulic system is designed for traversing the upper and lower carriages, as well as for extending and clamping the tailstock spindle.

The hydraulic system consists of:

a) one tandem vane pump (rapid traverse pump section has a delivery of 70 litres per min at a pressure of 15 to 20 atm and the working feed pump section has a delivery of 12 litres per min at a pressure of 25 to 30 atm) driven by a separate motor;

b) three hydraulic control panels of the upper and lower carriages;

c) hydraulic control panel for the upper carriage and for tailstock spindle travel and clamping;

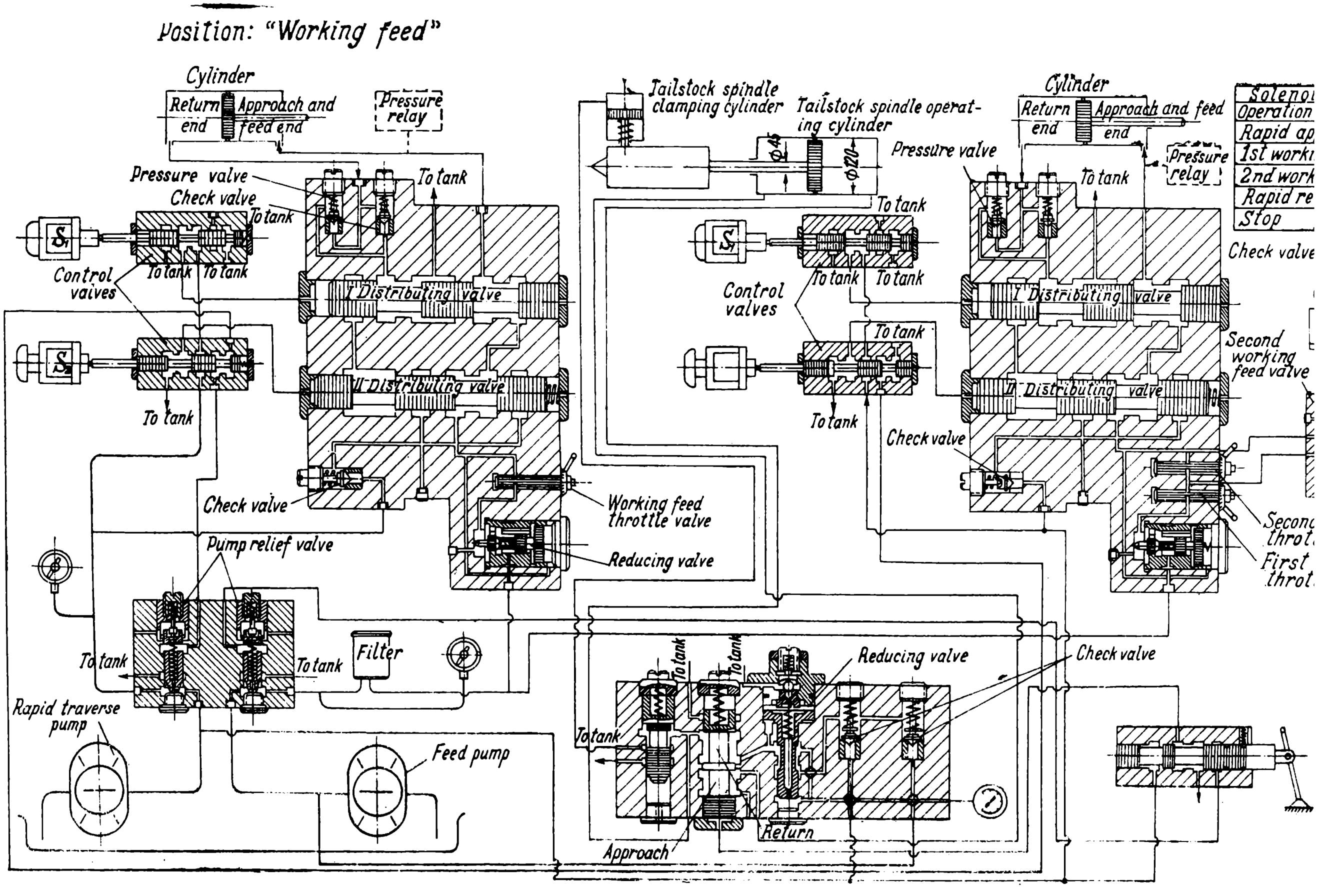


Fig. 154. Hydraulic system of semi-automatic lathes, model 1721.

d) hand-operated pilot valve for tailstock spindle travel;

e) hydraulic cylinders of the lower and upper carriages, and tailstock spindle and two cylinders for clamping the latter.

Carriage and tailstock spindle operation is *controlled* by the hydraulic panels which are connected to the delivery lines of the high and low pressure pump sections.

The hydraulic control panels of the carriages are devised so that oil may enter the cylinder of each carriage either from the high pressure pump section, without admitting oil from the low pressure section, or vice versa. In this way, with any combination of carriage movement, the pressures in the system are maintained constant to provide for independent carriage operation.

The hydraulic circuit and the control system enable an independent cycle to be obtained for each carriage. Such a cycle may comprise rapid approach, first working feed, second working feed of the lower carriage, rapid return, carriage stop in the initial position, and carriage stop at any point with consequent renewal of the cycle.

When both carriages operate on working feed or stand idle in their initial positions, the low pressure pump section discharges to the tank.

The high pressure pump section discharges to the tank when the tailstock spindle is retracted.

Control valves of the system are actuated by solenoids which are energised by limit switches or pressure relays.

The hydraulic control panel for clamping the tailstock spindle contains a check valve of the low pressure pump section, a check valve of the high pressure pump section, reducing valve, spindle clamping valve, and reversing valve.

The pilot valve for tailstock spindle control is hand-operated and is mounted on the front of the lathe. It has the following three positions:

a) *"Unclamp" with the spindle in its initial position.*

At the beginning of the cycle, when the workpiece has been unloaded, the tailstock spindle pilot valve is in the "Unclamp" position. The toolslides are in their initial positions and their control valves are in the "Stop" positions.

b) *"Clamp" to advance and clamp the tailstock spindle.*

After loading the blank to the line of centres, the operator presses the pilot valve handle, shifting the valve to the "Clamp" position. In this position, the end of the reversing valve piston is connected to the tank and a spring shifts this valve to the "Advance" position.

Oil from both pumps passes through the check valves of the tailstock control panel, reducing valve, and grooves of the reversing valve piston to the rear end of the cylinder to advance the spindle rapidly toward the headstock. The tailstock spindle advances until the tailstock centre forces the blank against the headstock centre, then the tailstock spindle stops.

This increases the pressure in the oil supply system and oil, under the shoulder of the clamping valve, shifts it to the "Clamp" position shown in the diagram. Here oil is admitted to the clamping cylinders to clamp the tailstock spindle.

The maximum clamping pressure is determined by the setting of the reducing valve in the tailstock control panel. A pressure range from 3 to 25 kg per sq cm is available.

c) "*Withdraw*"—*tailstock spindle withdrawal.* When the pilot valve is shifted to the "Unclamp" position, the reversing valve is shifted to its "Withdraw" position. In this position, oil from both pump sections passes through the check valves of the tailstock panel and is directed to the rod end of the tailstock spindle cylinder, withdrawing the spindle rapidly to the initial position.

In the "Withdraw" position, the low pressure pump discharges through the corresponding grooves of the control valve piston.

Setting up this semi-automatic consists in installing the required change gears, shifting the double cluster gears as required in the speed gearbox, adjusting the hydraulic system and setting the limit switches of the in-travel control system.

To install new change gears, the cover is removed from the change gear recess on the right end of the headstock. The cluster gears are shifted by turning the square shanks on the front wall with a wrench.

The tailstock is clamped on the bed by first tentatively tightening the screw which locates the tailstock between the bed ways, then the bolts holding the tailstock to the ways are drawn up firmly.

The carriages are set up independently of each other. The tooling or capacity chart of this machine is shown in Fig. 151.

The proper sequence in the operation of the hydraulic units is accomplished by a) setting the trip dogs which actuate the limit switches and the positive stops which determine the place at which the pressure relay is tripped and the initial positions of the carriages, and b) turning the rotary electric switch to the given cycle (automatic or setting-up operation).

Adjusting and setting up the hydraulic system. Before starting the lathe on an automatic cycle, the pump motor must be switched on and both carriages must be rapidly traversed alternately, by hand controls, from one extreme position to the other. This will eliminate air from the cylinders and pipelines. Smooth slide travel indicates that the air is removed. The same procedure should be followed for the tailstock spindle. Then the control panels for the slides and tailstock are adjusted and checked separately.

The relief valves in the system are set with the tailstock control lever in the "Clamp" position. The high pressure relief valve is checked by its own pressure gauge which should indicate a value from 25 to 30 kg per sq cm.

The low pressure relief valve is set, with one of the toolslides in the rapid advance or return position, so that its pressure gauge indicates from 15 to 20 kg per sq cm.

The maximum force with which the work is held against the headstock centre is adjusted by turning the screw of the reducing valve with the tailstock spindle in its extreme left position. The pressure should be within the range from 3 to 25 kg per sq cm.

The spring of the clamping valve is adjusted so that the tailstock spindle is clamped when the pressure in the system is from 5 to 10 kg per sq cm lower than the pressure for holding the work between the centres.

The electrical circuit (Fig. 155) provides for both setting up and automatic operation. Either mode of operation is selected by turning the rotary switch handle to the corresponding position.

1. *Automatic operation.* In accordance with the selector switch position, the lathe may operate on one of the following cycles: a) both carriages operate in parallel, b) the upper or lower carriage begins operating and then they operate consecutively, and c) only one carriage, upper or lower, is in operation.

For automatic operation, the selector switch is set to the "Automatic" position and the carriages are withdrawn to their initial positions to trip the initial position limit switches *1LSI*, *2LSI*, *3LSI*, and *4LSI* (Fig. 155 *a*) and the cycle switch is turned to the required operating cycle.

If the selector switch handle is in the vertical 0° position (Fig. 155 *c*) then, after pressing push button *5PB*, the spindle and pump motors are switched on. Both toolslides (upper and lower) advance rapidly to the work. Trip dogs actuate the limit switches *1LST* and *2LST* which change over to working feed. At the end of the cut, each toolslide independently changes over to rapid return. This is due to a pressure rise in their systems (when they reach their positive stops) which trips the pressure relays *1PR* and *2PR*. At the end of their return stroke, the slides trip the initial position limit switches *1LSI*, *2LSI*, *3LSI* and *4LSI* and stop in their initial positions.

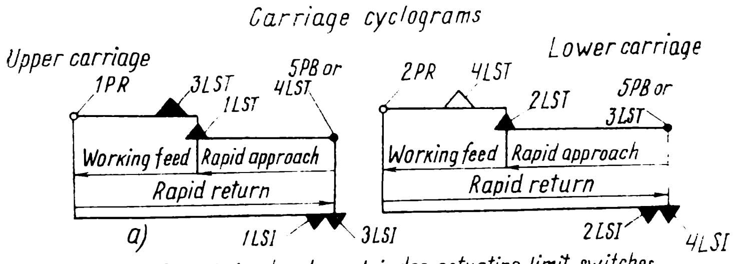
If the handle of the selector switch *SS* is positioned at an angle of —45°, which corresponds to consecutive carriage operation, the upper carriage will begin to operate first, after pressing the push button *5PB*. At the end of its working travel, the upper carriage will actuate the limit switch *3LS* which starts operation of the lower carriage.

With the handle of the selector switch in the —90° position, the lower carriage begins to operate and the upper carriage will be started by the lower. The carriages operate consecutively.

The switch handle positions at +45° and +90° correspond to operation of a single tool carriage, upper or lower, respectively.

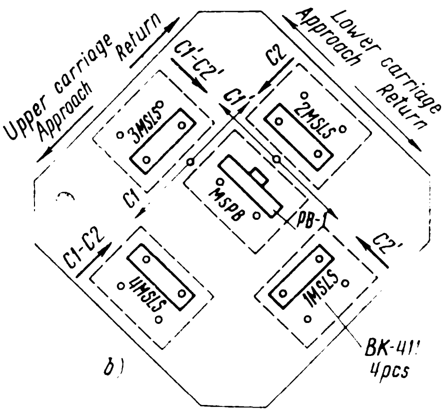
Any toolslide may be stopped at any point in the course of the cycle by pressing the "Feed-Stop" push button *6PB*. The slide or

Carriage cyclograms



Notes: Symbol ▲ denotes a trip dog actuating limit switches.
Trip dog 3LST(4LST) serves only for consecutive slide operation and is mounted on the slide (upper or lower) which starts first.
In all other cases, trip dog 3LST (4LST) must be removed.

Rotary master switch diagram



Selector switch contact sequence diagram

Section No.	Symbol on diagram	Automatic slide operation				
		Consecutive		Parallel	Separate	
		Starts first			Works alone	
		Lower	Upper	Upper Lower	Upper	Lower
		-90°	-45°	0°	+45°	+90°
1	MS1	−	+	−	+	
2	MS2	−	+	−		+
3	MS3		+	−	+	
4	MS4	+		−		+

Handle position

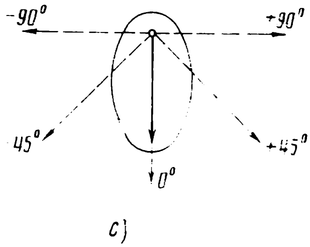


Fig. 155. Electrical control circuit diagram.
a—carriage cyclogram, *b*—rotary master switch diagram, *c*—selector switch handle positions.

slides will resume operation after pressing the "Cycle" push button *5PB*.

At the end of the operation, the spindle drive motor switches off and the spindle is stopped by an electromagnetic brake. A signal lamp lights to indicate that the operation has been completed.

2. *Setting up operation* consists in separate operation of the carriages. The rotary switch is turned to the setting up position. In this position, the spindle drive motor is switched on and off by push buttons. The upper and lower tool carriages are controlled by the handle and push button of a rotary master switch. Turning the handle to one of its positions corresponds to working feed, toward the spindle, of one of the toolslides. If, in addition, the push button *MSPB* is pressed, rapid advance or return in the same direction will be obtained. Spindle and toolslide operation can be started in setting up, only after switching on the hydraulic pump motor.

The electric coolant pump is switched on and off together with the spindle drive motor. If necessary, it may be controlled separately by a switch.

Setups. The highest rate of production in a multiple-tool setup will be achieved if the whole length of the cut is divided between the maximum feasible number of tools operating simultaneously. Limiting factors, in this respect, are the available power of the lathe, the rigidity of the workpiece, and the space available for arranging the tools. Roughing and finishing operations are usually performed separately on multiple-tool semi-automatics.

Table 22 illustrates an example of machining on the semi-automatic, model 1721.

§ 94. TRACER-CONTROLLED SEMI-AUTOMATIC LATHE, MODEL 1722

This semi-automatic lathe has the same specifications, general arrangement, gear trains, and hydraulic system as the multiple-tool semi-automatic, model 1721. The principal difference between these semi-automatics is that model 1722 has an upper tracer-controlled toolslide which enables a workpiece to be turned with a single tool to duplicate a template or master model.

The lower slides may turn deep grooves and face shoulders, i. e., those elements that cannot be turned with the tracer-controlled slide due to the form of the tool.

Tracer-controlled machining provides for a sharp increase in the rate of production due to the reduction in the time required for changing over (because of the small number of tools), the possibility of employing higher speeds and feeds, and a decrease in the number of measurements required.

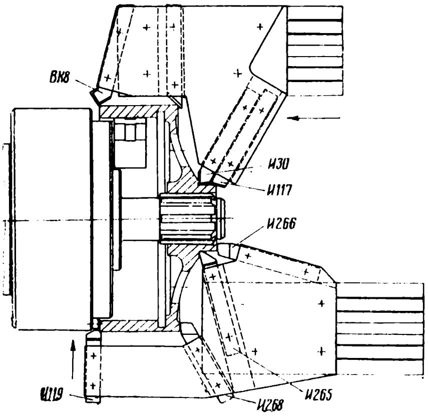
The following features are inherent to this lathe:

1) ample power and high rigidity enabling up-to-date cemented carbides to cut heavy chips at high speeds;

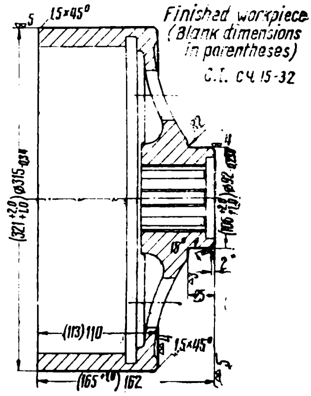
Table 22

Tooling Layout and Operation Sheet for the Multiple-Tool Semi-Automatic Lathe, Model 1721

<table>
<tr><td colspan="2" rowspan="2">Hydraulic Multiple-Tool Semi-Automatic Lathe, Model 1721</td><td colspan="4">Material: casting СЧ 15-32</td></tr>
<tr><td colspan="4">Speed gearbox</td></tr>
<tr><td>Maximum cutting speed, m/min</td><td>Spindle speed, rpm</td><td colspan="2">Double cluster gear position</td><td colspan="2">Change gears</td></tr>
<tr><td>60/20</td><td>59</td><td>R. H.</td><td>L. H.</td><td>A</td><td>B</td></tr>
<tr><td>Floor to-floor time, min</td><td>4.3</td><td rowspan="2">II</td><td rowspan="2">I</td><td rowspan="2">27</td><td rowspan="2">54</td></tr>
<tr><td>Machining time, min</td><td>4.0</td></tr>
</table>



Tooling layout



Sketch of workpiece

<table>
<tr><th rowspan="2">Slide</th><th rowspan="2">Operation element</th><th rowspan="2">Travel, mm</th><th rowspan="2">Feed, mm/min</th><th rowspan="2">Feed, mm/rev</th><th rowspan="2">Spindle revolutions required</th><th colspan="2">Consecutive spindle revolutions</th><th rowspan="2">Machining time, min</th></tr>
<tr><th>start</th><th>finish</th></tr>
<tr><td>Lower</td><td>Face ends and chamfer 1.5×45° on diam 315 mm</td><td>23</td><td>18</td><td>0.3</td><td>(77)</td><td>(155)</td><td>(232)</td><td>(1.3)</td></tr>
<tr><td>Upper</td><td>Turn diam $315_{-0.34}$ and $92_{-0.23}$, chamfer 1.5×45° on diam 315 and 2×15° on diam 92 mm . . . .</td><td>116</td><td>29.5</td><td>0.5</td><td>232</td><td>0</td><td>232</td><td>4.0</td></tr>
</table>

Time for idle motions, 0.3 min

$\Sigma n_0 = 232$ revolutions; $t_w = \frac{232}{59} \approx 4$ min.

2) high versatility providing for tracer-controlled machining of a large variety of work;

3) reliable protection against flying chips which is very important for operation at high cutting speeds;

4) close arrangement of the work, tools, and the operator's position ensuring convenient loading and unloading, work measurement, setting up and adjustments;

5) unhindered chip disposal from the toolslides.

General Arrangement. The ways for the tracer-controlled (longitudinal) slide carriage are located at the upper part of the bed; the ways at the lower part accommodate one or two facing (cross) toolslide carriages.

The upper ways are of the flat type, induction hardened and precisely ground. The lower slides are protected against chips by a system of shields.

The headstock and the hydraulic cylinder for traversing the upper tracer-controlled slide saddle are fastened on the left-hand side of the bed. The right-hand side of the bed carries the toolslide carriages and the cylinder which actuates the facing slides. Racks with slots for fastening positive stops of the slides are mounted above and below, adjacent to the ways.

A bracket, on the right end of the bed, carries a screw for adjusting the tailstock along the bed.

An opening in the central part of the bed serves for chip disposal. This opening may also be used for accommodating a conveyer, when the lathe is built into an automatic transfer machine, or for ejecting the finished work if a magazine feed device is installed.

The bed rests on two base members; one houses the main drive motor and the other contains hydraulic system components.

Headstock and tailstock are unified with and therefore identical to the same units in the multiple-tool semi-automatic, model 1721.

Carriages or toolslides. The machine has three carriages; one tracer-controlled (Fig. 156) and two facing carriages (Fig. 157). The tracer-controlled carriage comprises the saddle, which is traversed by a hydraulic cylinder longitudinally along the bed, and upper slide which has a cross (tracer-controlled) movement in reference to the saddle. This movement is obtained from a cylinder mounted on the upper slide. The duplicating motion of this cylinder is controlled by a tracer head which comprises a stylus and an automatic regulator (Fig. 158). The latter transmits the required work signals in accordance with the profile of a template or contour of a prototype workpiece (or model). The tool block of this slide may be adjusted to properly position the tools in reference to the line of centres. A channel is provided in the tool block for passage of the cutting fluid to the cutting edges of the tools.

The cylinder housing, mounted on the upper slide, carries the stylus valve. To obtain the correct diametral dimensions on the

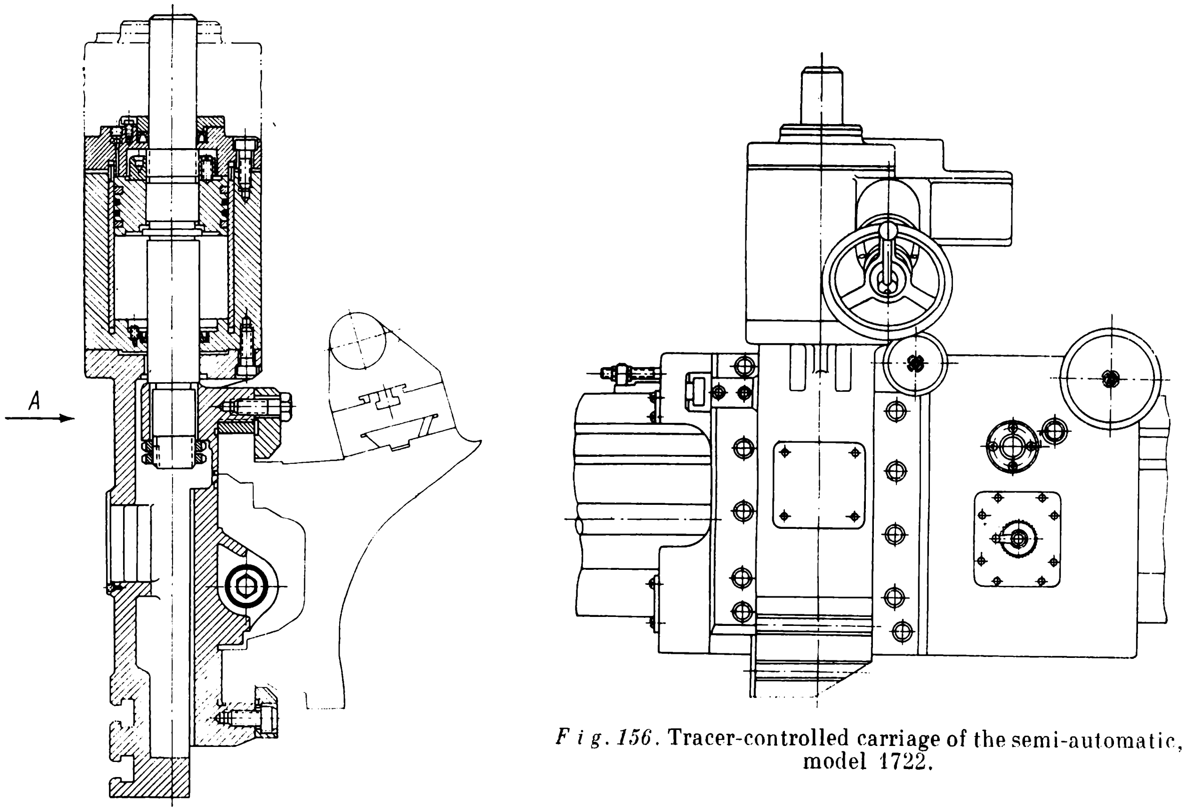
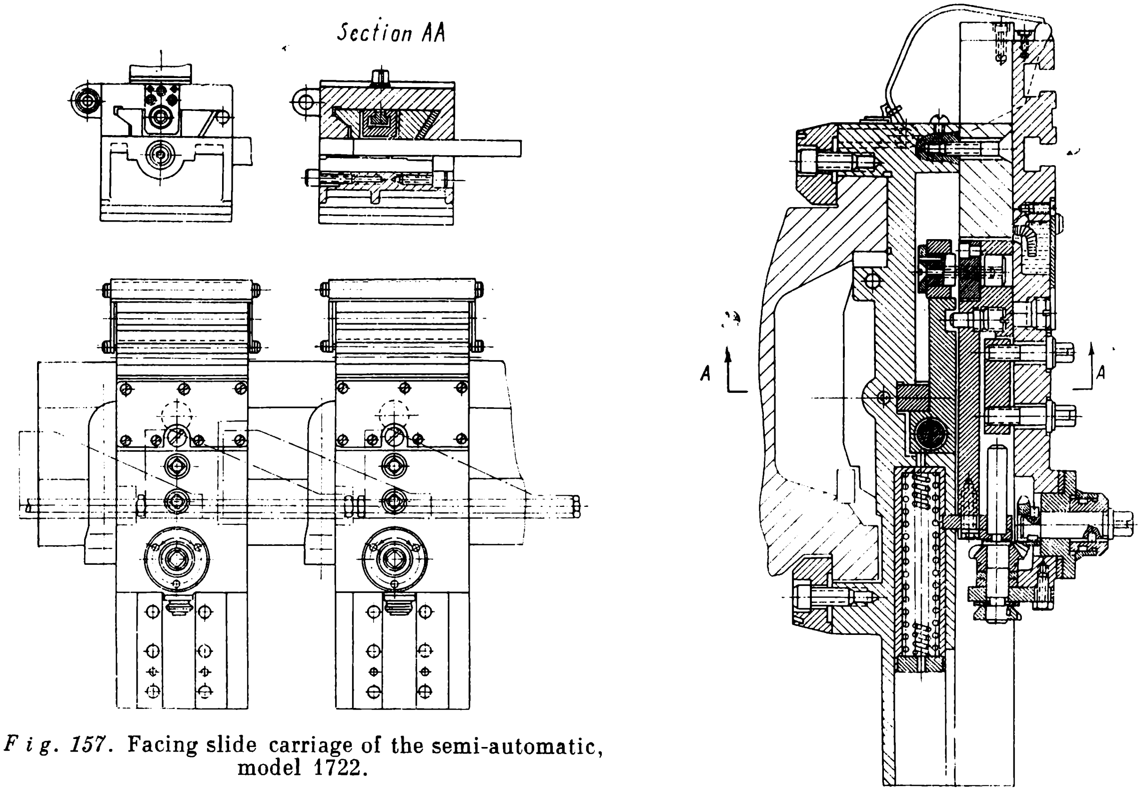
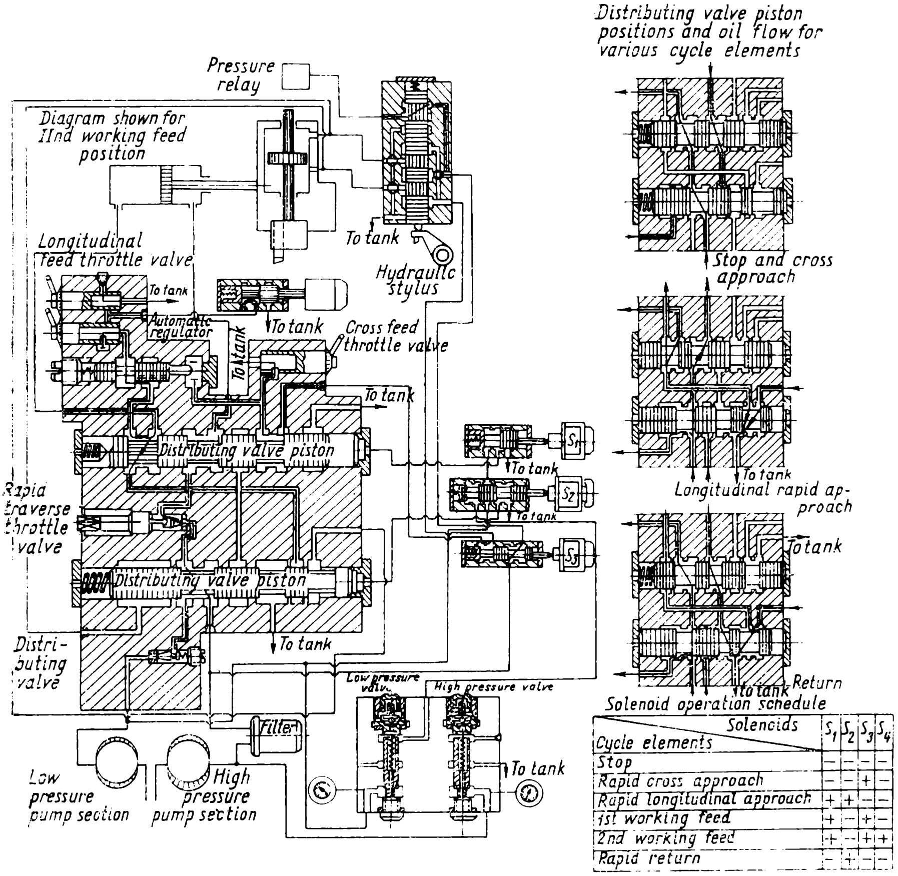


Fig. 156. Tracer-controlled carriage of the semi-automatic, model 1722.



F i g. 157. Facing slide carriage of the semi-automatic, model 1722.


Distributing valve piston positions and oil flow for various cycle elements
Pressure relay
Diagram shown for IInd working feed position
Longitudinal feed throttle valve
To tank
Automatic regulator
To tank
To tank
Hydraulic stylus
Cross feed throttle valve
To tank
Distributing valve piston
Rapid traverse throttle valve
Distributing valve piston
Distri-buting valve
To tank
S_1
To tank
S_2
To tank
S_3
Low pressure valve
High pressure valve
To tank
Filter
Low pressure pump section
High pressure pump section
Stop and cross approach
To tank
Longitudinal rapid approach
To tank
To tank
Return
Solenoid operation schedule

Solenoids / Cycle elements	S_1	S_2	S_3	S_4
Stop	–	–	–	–
Rapid cross approach	–	–	+	–
Rapid longitudinal approach	+	+	–	–
1st working feed	+	–	+	–
2nd working feed	+	–	+	+
Rapid return	–	+	–	–

Fig. 158. Hydraulic system diagram for the tracer-controlled slide carriage of semi-automatic lathe, model 1722 (shown in second working feed position).

workpiece, means are available for varying the distance between the tip of the stylus and the tool nose in a vertical plane. To this end, the stylus valve, its actuating lever, and the tip, tracing the template profile, are arranged on a slide having vertical adjustment on the cylinder housing. This slide is adjusted by a handwheel through a screw. The handwheel is mounted on a bracket fastened to the cylinder housing. The adjusting slide is locked in the adjusted position by means of an eccentric clamp having a lever on the same axis with the stylus adjusting handwheel.

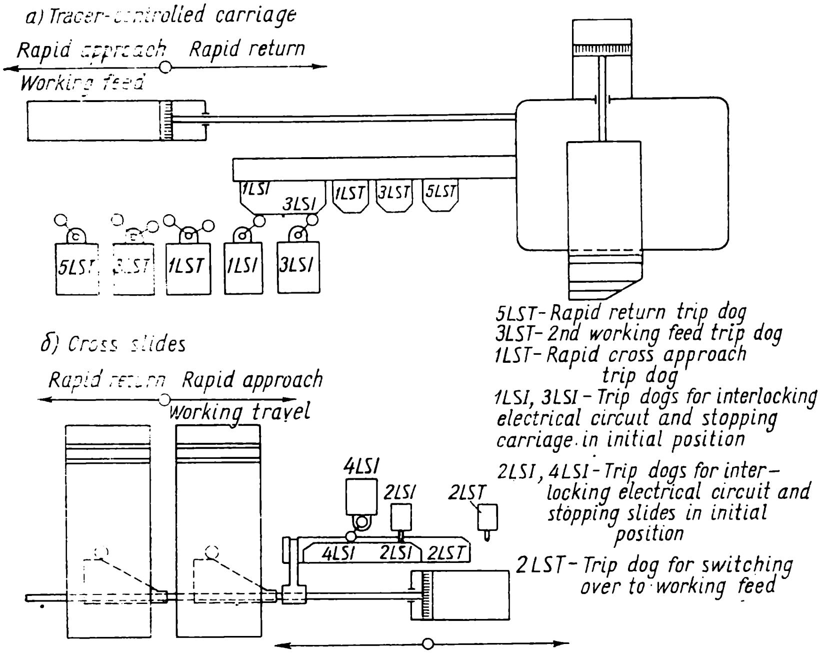
Two handwheels are mounted directly on the saddle of the tracer-controlled carriage. One serves for adjusting the prototype workpiece or template in an axial direction (to co-ordinate the positions of the tool nose and stylus tip in an axial direction) while the second handwheel controls the stylus stop. This latter is used for turning the workpiece in several cuts without changing the distance between the stylus tip and the tool.

The stylus stop is employed, mainly, in cases when the allowance is to be turned off in a number of cuts. In this case, the stop is adjusted so that the stylus tip does not contact the template but the tool cuts off a part of the provided allowance. The full allowance is turned off gradually by releasing the screw of the stop the required amount after each cut. Before the last cut, the screw is released to allow the stylus tip to contact the template or prototype workpiece.

The stylus stop also enables cylindrical workpieces to be turned without the need of a template or prototype workpiece.

The tracer-controlled slide ways are lubricated by a hand-feed lubricator mounted on the longitudinal saddle.

Carriage travel control (switch-over from one cycle element to the next) is accomplished by a pressure relay and limit switches mounted on the left-hand side of the lathe over the headstock (Fig. 159). A trip-dog bar, arranged near the switches and having T-slots, is rigidly fastened to the longitudinal saddle of the carriage. During carriage travel, trip dogs, mounted in the T-slots, trip the limit switches to engage the required elements of the operating cycle.


a) Tracer-controlled carriage
Rapid approach
Rapid return
Working feed
1LSI
3LSI
1LST
3LST
5LST
5LST
3LST
1LST
1LSI
3LSI
б) Cross slides
Rapid return
Rapid approach
Working travel
4LSI
2LSI
2LST
4LSI
2LSI
2LST
5LST - Rapid return trip dog
3LST - 2nd working feed trip dog
1LST - Rapid cross approach trip dog
1LSI, 3LSI - Trip dogs for interlocking electrical circuit and stopping carriage in initial position
2LSI, 4LSI - Trip dogs for interlocking electrical circuit and stopping slides in initial position
2LST - Trip dog for switching over to working feed

F i g. 159. Limit switch and trip dog setup on the semi-automatic lathe, model 1722.

The facing carriages serve to turn grooves and to face shoulders. They may be set up in any position along the bed, between the headstock and their actuating cylinder. The saddles of the carriages are clamped to the bed at the required positions by gibs and stops.

The hydraulic cylinder (Fig. 150), actuating the facing slides, is located at the right-hand side of the bed, near the end face. The piston rod of this cylinder is linked, through a threaded tie-rod and thrust nuts, with a cam bar which slides in special guides provided in the stationary saddles of these carriages. The motion of the cam bar actuates a follower roll with a slide block fastened to the upper (cross) slide. The latter is held to the cam bar by springs which also retract the slide at the end of the operation.

The form of the workpiece may be such that one facing slide is sufficient to perform the required operation. In this case, the other carriage is positioned under the tailstock beyond the working zone. To be accommodated under the tailstock, the upper slide must be adjusted in relation to its slide block to its extreme lower position.

The mechanism for mounting the template or prototype workpiece consists of a bracket, on which the template is secured, and a device for longitudinal adjustment. This latter enables proper linear co-ordination to be achieved between the template and the cutting tool. The template bracket is adjusted longitudinally by a handwheel through bevel gears on the tracer-controlled carriage and a rod arranged along the upper bed ways. The threaded end of the rod is screwed into a nut fastened to the template bracket. Handwheel rotation adjusts the template bracket 15 mm in either direction.

The template bracket may be replaced by a special plate for operation with a prototype workpiece. Adjustable stocks with centres are mounted on this plate and the prototype is held between the centres.

The coolant system and slide lubrication are the same as for the model 1721 semi-automatic.

Hydraulic drive. The semi-automatic lathe has two main independent hydraulic systems, supplied from a single tandem-type pump. This pump also supplies the auxiliary hydraulic system for actuating the tailstock spindle.

Duplicating is accomplished by the hydraulic tracing system which operates in the following manner: the stylus tip, contacting and sliding along the profile of the template (see Figs. 157 and 158), displaces the stylus valve piston in the direction corresponding to the rise or fall of the template profile. This admits oil into the cross feed cylinder of the tracer-controlled slide which then travels in a direction corresponding to the template profile. Since the stylus valve housing is rigidly fastened to the slide, the travel of the latter will continue until the port for admitting oil to the cross feed cylinder is closed by the motion of the stylus valve housing. In this way, the slide reproduces the motion of the stylus tip.

An increase in the speed of crosswise motion of the slide automatically decreases the longitudinal feed of the saddle. The relation and rates of these feeds are set by the corresponding throttle valves through which oil escapes (see Fig. 158).

The hydraulic system of the cross slides is designed for "metering-in" control by means of a reducing valve, provided to maintain a constant pressure drop in the throttle valve.

Slide and tailstock spindle control is accomplished by hydraulic control panels connected to the delivery lines of the high and low pressure pump sections.

The hydraulic control panels are devised to supply each of the carriage cylinders from the high pressure pump section with the low pressure section shut out, or vice versa. In this manner, the pressures in the systems are constant and provide for fully independent operation of the slides.

When all slides operate on working feed or stand in their initial positions, the low pressure pump section discharges to the tank.

The high pressure pump section discharges when the tailstock spindle is unclamped.

The hydraulic systems of the slides are controlled by solenoids which are energised by electrical travel-control devices such as limit switches and pressure relays (see Fig. 159).

The required switching-over sequence of the hydraulic units for any given cycle is obtained by setting the trip dogs which close the limit switches and by setting the rotary selector switch to the required mode of operation (for either automatic or setting-up operation).

The tracer-controlled and facing slides are set up independently.

Setting up. The tracer-controlled semi-automatic, model 1722, is prepared for machining a definite workpiece on setting-up operation. It may be switched over to the semi-automatic cycle only after successfully turning a test piece.

The mode of operation is established by a rotary selector switch on the control panel. In regular semi-automatic operation, the operator loads and clamps the blank and then starts the lathe by pressing the "Cycle" push button. The lathe stops automatically at the end of the operation after the slides have been withdrawn.

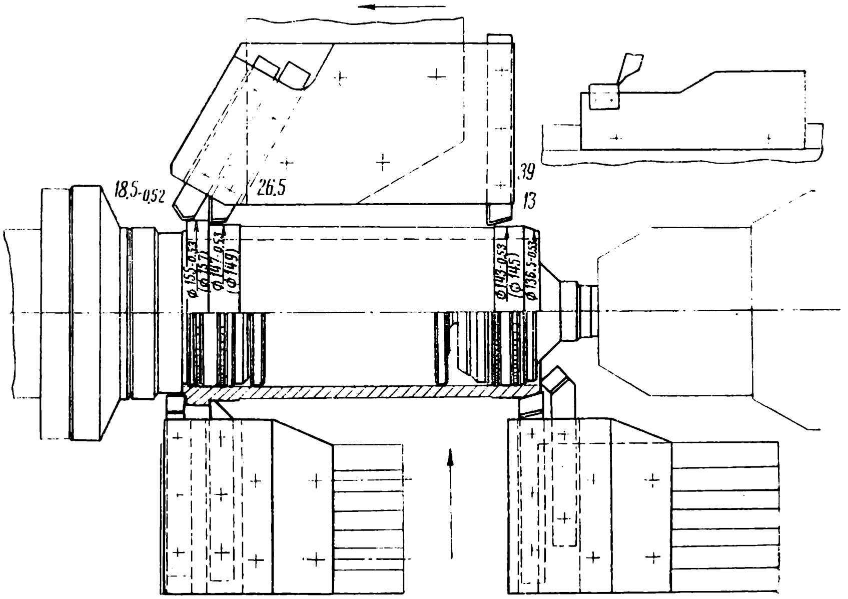
Several semi-automatic operating cycles are available. They are set up by the universal selector switch on the control panel and include: a) both toolslides start together and operate in parallel, b) the tracer-controlled slide begins to operate first and the lower slides start at a preset time, and c) only the tracer-controlled slide is in operation (lower slides are switched off).

In setting up operation the toolslides are manually controlled by means of a special handle on the setting-up control panel. This handle provides both rapid traverse and working feed of all slides in all directions.

Table 25

Tooling Layout and Operation Sheet for the Tracer-Controlled Semi-Automatic Lathe, Model 1722

Maximum cutting speed, m/min	Spindle speed, rpm	Blank	Casting	Change gears	
71.4	143	Material: C. I. СЧ 21-40		A	B
		Part name	Sleeve	36	45
Floor-to-floor time, min	1.5	Machining time, min		1.2	



Tooling layout

Slide	Operation element	Travel, mm	Feed, mm/min	Feed, mm/rev	Spindle revolution required	Consecutive spindle revolutions		Machining time, min
						Start	Finish	
Tracer-controlled	Turn diam $155_{-0.53}$, $147_{-0.53}$, and $143_{-0.53}$	60	71.5	0.5	120	50	170	0.84
Lower	Face ends and chamfer to diam $136.5_{-0.53}$	15	42.9	0.3	50	0	50	0.36

Time for idle motions, 0.3 min

The elements of the above-mentioned cycles are switched over by trip dogs mounted on bars which travel together with the tracer-controlled and facing slides (see Fig. 159). These trip dogs actuate the corresponding limit switches.

A tooling layout and operation sheet for the hydraulic tracer-controlled semi-automatic, model 1722, are illustrated in Table 23.

§ 95. PROGRAMME-CONTROLLED SEMI-AUTOMATIC LATHE, MODEL 1722П

Model 1722П is a standard tracer-controlled semi-automatic lathe, model 1722, described in § 94, to which programme control has been applied (Fig. 160*a*).

This semi-automatic is designed for turning separate blanks produced by hammer forging or by rolling, i. e., blanks with comparatively large machining allowances that must be removed in several cuts. This lathe enables the rate of production to be substantially increased in small- and medium-lot production on such work as stepped shafts.

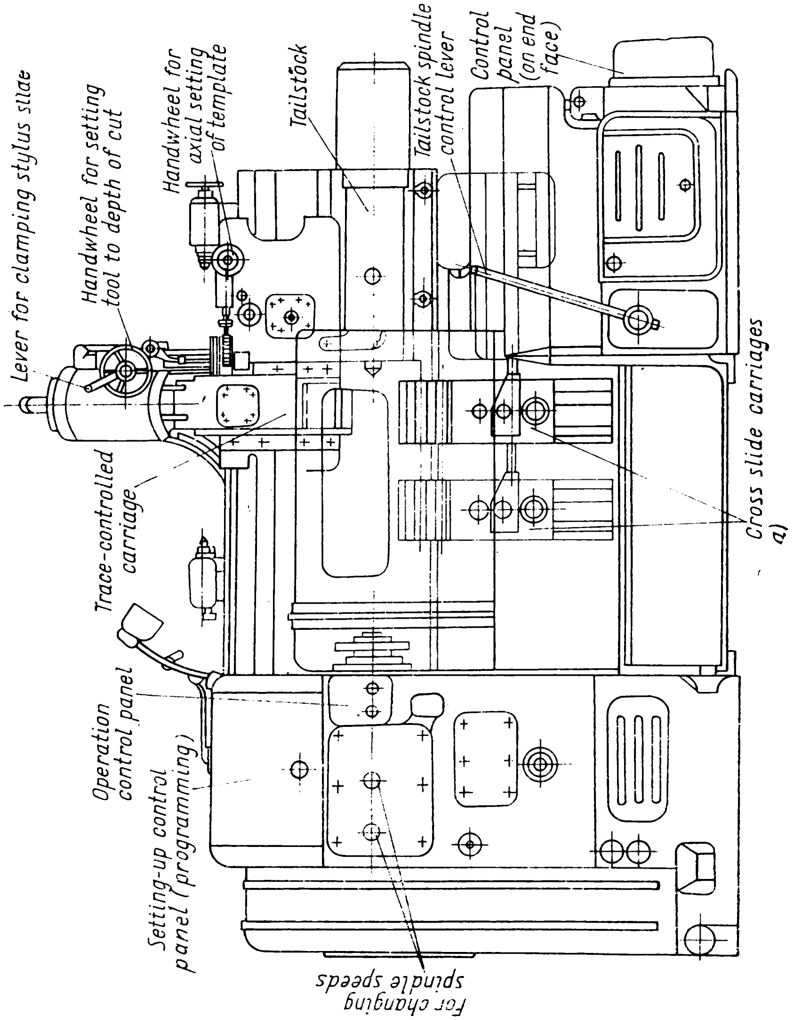
The programming facilities provide for setting up a cycle in minimum time and also reduce handling time in operation.

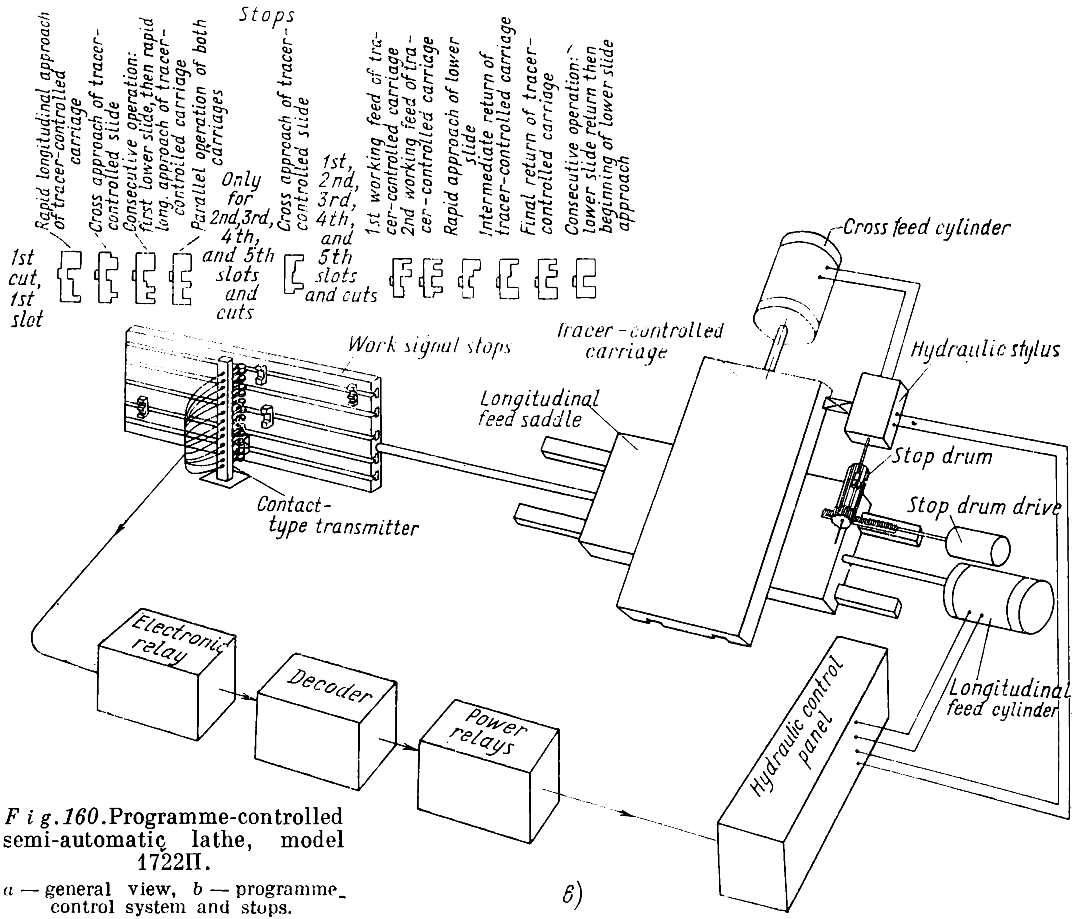
The *construction* of the semi-automatic, model 1722П, is the same as the line of tracer-controlled lathes (see Fig. 147). The tracer-controlled carriage travels along ways at the upper part of a highly rigid frame type bed, between the headstock and tailstock. Two facing carriages are mounted on the lower ways.

The tracer-controlled carriage (see Fig. 156) comprises the saddle, traversed along the bed by a hydraulic cylinder, located at the upper left side of the bed, and the upper slide which has a cross (tracer-controlled) movement. Cross movement of this slide is obtained from a cylinder and piston rod controlled by a hydraulic stylus and automatic regulator (see Fig. 158).

Carriage travel control (switch-over from one cycle element to the next) is accomplished by a pressure relay, contact-type transmitter, and stops arranged above the headstock. A plate with stops (or with a punched card) is also located here. The plate is rigidly fastened to the saddle of the tracer-controlled carriage. Upon carriage travel, the stops (or punched card) pass by the stationary contact-type transmitter and switch on the required element of the cycle (Fig. 160 *b*).

A stop drum is mounted on the saddle of the tracer-controlled carriage. This drum is used for multiple cut turning of workpieces with machining allowances larger than can be feasibly removed in one cut. The drum has six slots for clamping stops which enable five cuts to be made without changing the distance between the tool nose and stylus tip, i. e., to a stop. The sixth (last) cut is made with the stylus tracing the template.


Lever for clamping stylus slide
Handwheel for setting tool to depth of cut
Handwheel for axial setting of template
Tailstock
Tailstock spindle control lever
Control panel (on end face)
Cross slide carriages
a)
Trace-controlled carriage
Operation control panel
Setting-up control panel (programming)
For changing spindle speeds


Stops
1st cut, 1st slot
Rapid longitudinal approach of tracer-controlled carriage
Cross approach of tracer-controlled slide
Consecutive operation: first lower slide, then rapid long. approach of tracer-controlled carriage
Parallel operation of both carriages
Only for 2nd,3rd, 4th, and 5th slots and cuts
Cross approach of tracer-controlled slide
1st, 2nd, 3rd, 4th, and 5th slots and cuts
1st working feed of tracer-controlled carriage
2nd working feed of tracer-controlled carriage
Rapid approach of lower slide
Intermediate return of tracer-controlled carriage
Final return of tracer-controlled carriage
Consecutive operation: lower slide return then beginning of lower slide approach
Cross feed cylinder
Work signal stops
Tracer-controlled carriage
Hydraulic stylus
Longitudinal feed saddle
Stop drum
Stop drum drive
Contact-type transmitter
Electronic relay
Decoder
Power relays
Hydraulic control panel
Longitudinal feed cylinder
б)

F i g. 160. Programme-controlled semi-automatic lathe, model 1722П.

a — general view, *b* — programme control system and stops.

Stylus stops, corresponding to the cuts, are clamped in the drum slots so that the stylus tip does not contact the template but the tool cuts off a part of the remaining allowance. The drum indexes after each cut, presenting a new stop which is lower than the preceding stop by the depth of the cut and the tool gradually removes the allowance. No stop is set up in the slot for the last cut. In this case, the stylus advances to contact the template and the slide with the tool reproduces the profile of the template on the workpiece.

The facing carriages may be set up at any position along the bed to suit the facing cuts on the work (see Fig. 157).

Cross movement of the facing slides is actuated by a hydraulic cylinder located on the right-hand side in the front of the lathe. The piston rod of this cylinder is linked, through a threaded tie-rod and thrust nuts, with a cam bar which slides in special guides provided in the stationary saddles of these carriages.

The facing tools are adjusted in length by moving the upper slide in relation to the slide block. The slide block is fastened to the cross slide with one adjusting and two fastening screws.

Cross slide movement is controlled by a bar with trip dogs linked to the piston rod of the hydraulic cylinder. These trip dogs close limit switches mounted on the cylinder housing.

The hydraulic drive of the model 1722П semi-automatic is designed for actuating the tracer-controlled and facing slides, for extending and clamping the tailstock spindle, and for indexing the stylus stop drum.

The hydraulic system of the tracer-controlled slide operates by the two-co-ordinate duplicating system.

An increase in speed of crosswise motion of the slide automatically reduces the longitudinal feed of the saddle. The relation and rates of these feeds are set by the corresponding throttle valves through which oil escapes ("metering-out" system).

Cycles. Semi-automatic and setting-up modes of operation are available on the semi-automatic lathe.

The mode of operation is established by a rotary selector switch on the control panel. In semi-automatic operation, the lathe is started by pressing the "Cycle" push button. The lathe stops automatically at the end of the operation, after the slides have returned.

Several semi-automatic operating cycles are available. They are set up by stops and include:

a) tracer-controlled and facing slides start together;

b) the facing slide or slides begin operating first and at the end of their travel, the tracer-controlled slide begins operating;

c) the tracer-controlled slide begins operating while the facing slides are engaged in the preset cut;

d) only the tracer-controlled slide is in operation (facing slides are switched off).

Instead of the ordinary trip dogs, contact change-over switches and rotary master switch, this semi-automatic lathe is equipped with special stops enabling a sequence of work signals to be obtained in addition to checking the movements of the operative units. This system also allows the programme of the operating cycle to be prepared separately from the lathe.

The programme-control system is of the in-travel type and consists of the following principal units: 1) electrical-contact-type transmitter, 2) set of stops, 3) electronic relays, 4) relay circuit decoder, and 5) power relay circuit.

The contact-type transmitter has 27 low-current control contacts and is attached rigidly on the bed.

Each possible command or work signal corresponds to a definite combination of closed contacts. By using sets of four contacts, any of 15 possible commands may be transmitted.

The stops are profiled cams with a definite combination of projections and recesses.

If such a stop travels in reference to the contact-type transmitter, certain contacts will be shorted to the body of the lathe. This will close the corresponding electronic relays and a special relay decoder circuit will transmit the required work signal to the power relay circuit.

The stops for controlling the operating cycle are mounted on a plate rigidly fastened to the saddle of the tracer-controlled slide.

Each contact of the transmitter is connected to the input of its electronic relay which is designed as a single stage amplifier. The coil of the electromagnetic relay *PR* is connected to the plate circuit of the amplifier tube.

The contacts of all such relays close the corresponding relays of the decoder. A combination of decoder relay contacts form the decoder circuit. The output of this latter circuit is connected to the power relays which directly control the movements of the operative units.

The contacts of the transmitter are divided into five groups of five contacts each. Each group controls one cut in the operation. Two contacts, not included in the groups, fix the initial position of the template.

If the cycle is to be set up outside of the lathe, a punched card of stiff cardboard is employed in place of the stops. The punched card is layed out in length and the required contact combinations are obtained by punching holes at the required places. Such cards may be rolled up and stored for future use.

A two-way selector switch is used to control the facing and tracer-controlled slides in setting-up operation.

The sequence of cuts in turning a stepped shaft on the semi-automatic, model 1722П, is shown in Fig. 161.

The first four cuts are controlled, as concerns diameter and length dimensions, by the programming device; the fifth cut is tracer-controlled.

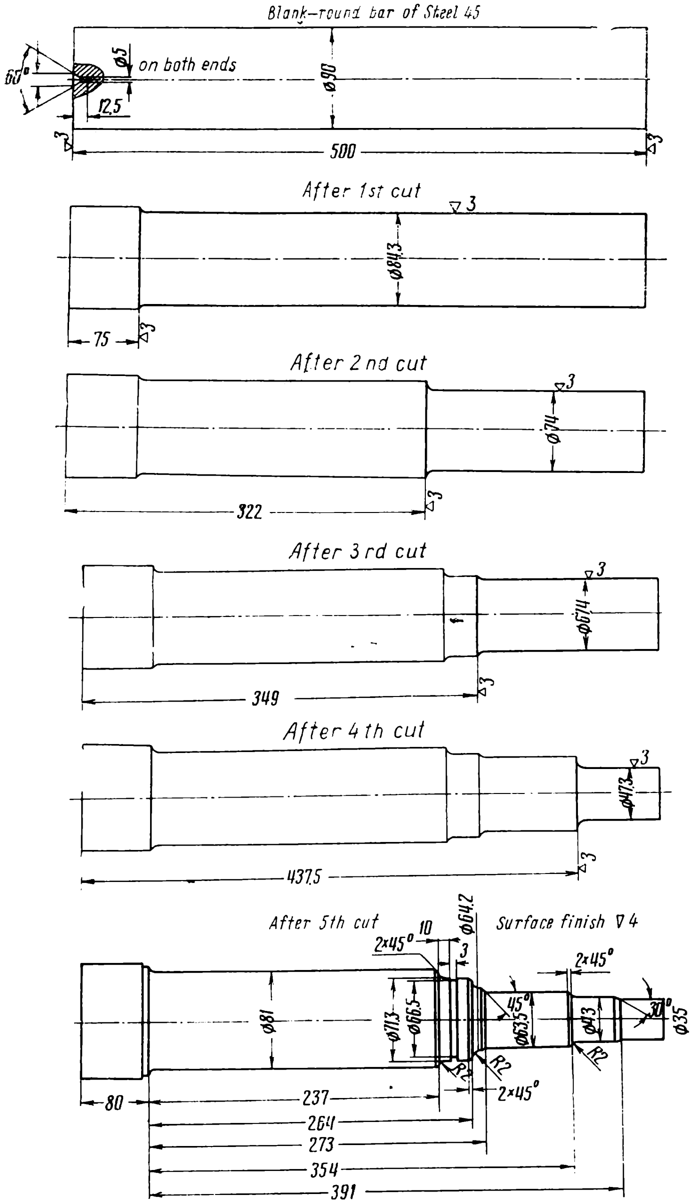


Fig. 161. Machining sequence of a stepped shaft in five cuts on the semi-automatic lathe, model 1722П.

§ 96. VERTICAL SINGLE-SPINDLE SEMI-AUTOMATIC LATHE, MODEL MP4H

The vertical semi-automatic, model MP4H (Fig. 162) is designed for turning large forgings, from 250 to 500 mm in diameter and from 65 to 200 mm in height, at high cutting speeds with cemented-carbide tipped tools. A power of 55 kw is available. The lathe has a hydraulic drive and electrical controls based on the in-travel or sequential principle. The vertical arrangement of this lathe imparts high rigidity and vibration-proof qualities and enables considerable floor space to be saved in comparison with similar horizontal lathes.

The main drive motor and the spindle are arranged in the base (Fig. 163). The hydraulic chucking device is inside the spindle (Fig. 164).

The main drive motor (see Fig. 163) transmits power through a flexible coupling to the drive shaft. From here, rotation is transmitted through spiral bevel and helical gearing to the spindle. Spindle speeds are varied by change gears. A shoe brake is provided to stop the spindle quickly after switching off the drive.

Three independent carriages are mounted on the semi-automatic. They are the longitudinal, boring, and cross carriages. All toolslides have hydraulic feeds which may be quickly changed over when necessary.

The longitudinal carriage has longitudinal travel actuated by a hydraulic cylinder and upper cross slide travel controlled by a cam bar through a roll (Fig. 164).

The upper cross slide of this carriage is adjusted crosswise to suit the workpiece diameter. During carriage movement, the trip dogs close the corresponding limit switches to change over from rapid approach to working feed, to engage slow feed and to stop the carriage in its upper position. Working travel is limited by a positive stop.

During operation, the upper cross slide is held against the cam bar with heavy springs. Two bevelled bars are mounted on the rear side of the cam bar; one bevelled bar is shifted at the end of the cut, in reference to the other, by a trip dog mounted on the cam bar. This allows the upper cross slide to retract by spring action from the work. This tool relief device, similar to the one shown in Fig. 153, allows the carriage to return to its initial position with the tools withdrawn from the workpiece surface.

The cross carriage (see Fig. 164) consists of a saddle in which a slide block, rigidly secured to the upper cross slide, travels. The slide block is actuated by a roll and a cam bar, linked to the piston rod of a hydraulic cylinder. The cross slide is controlled in the same way as the longitudinal slide.

The boring carriage (see Fig. 164) consists of the housing in which a ram travels. The ram contains a hydraulic cylinder. The rod and piston are rigidly fastened to the housing. Oil is delivered to the upper

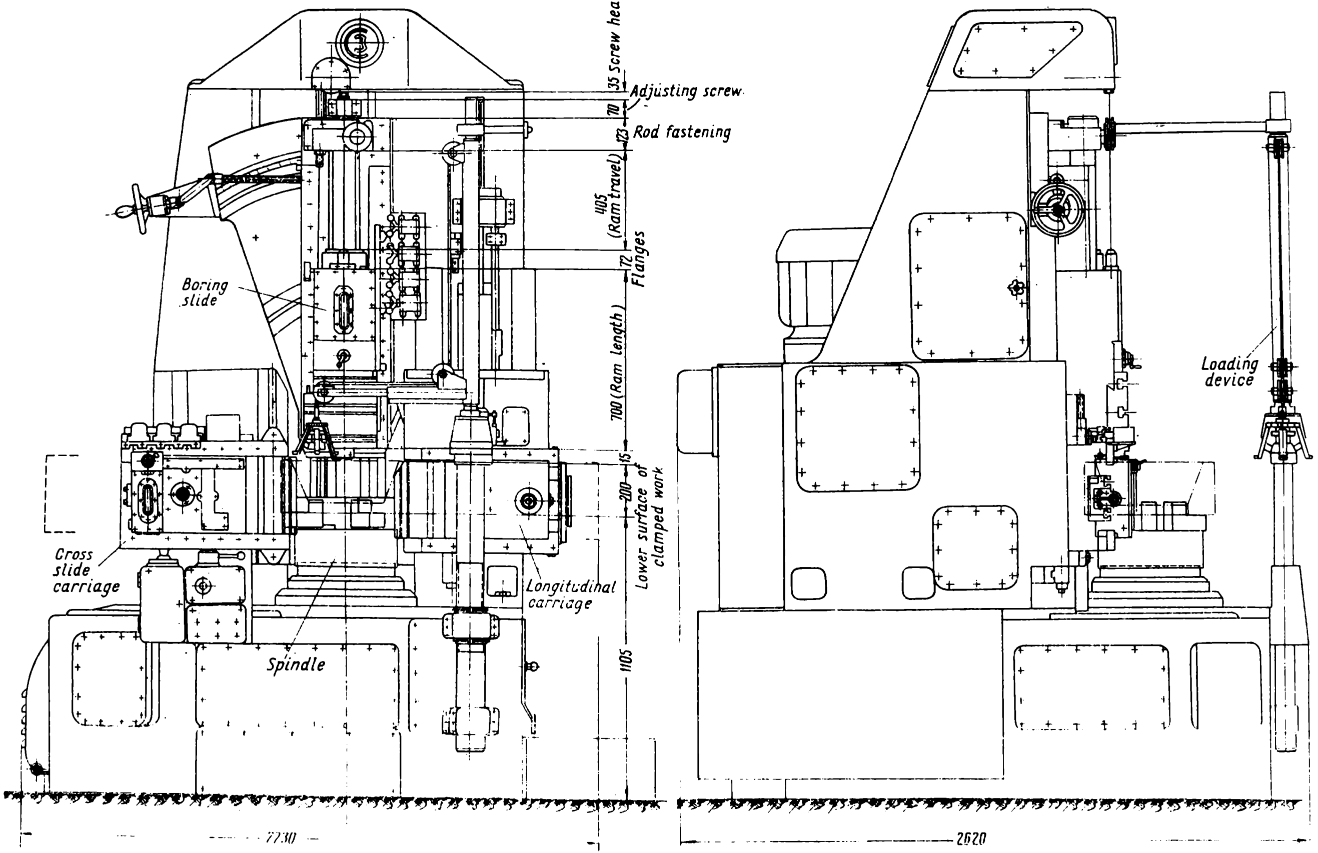


Fig. 162. Vertical single-spindle semi-automatic lathe, model MP41L.

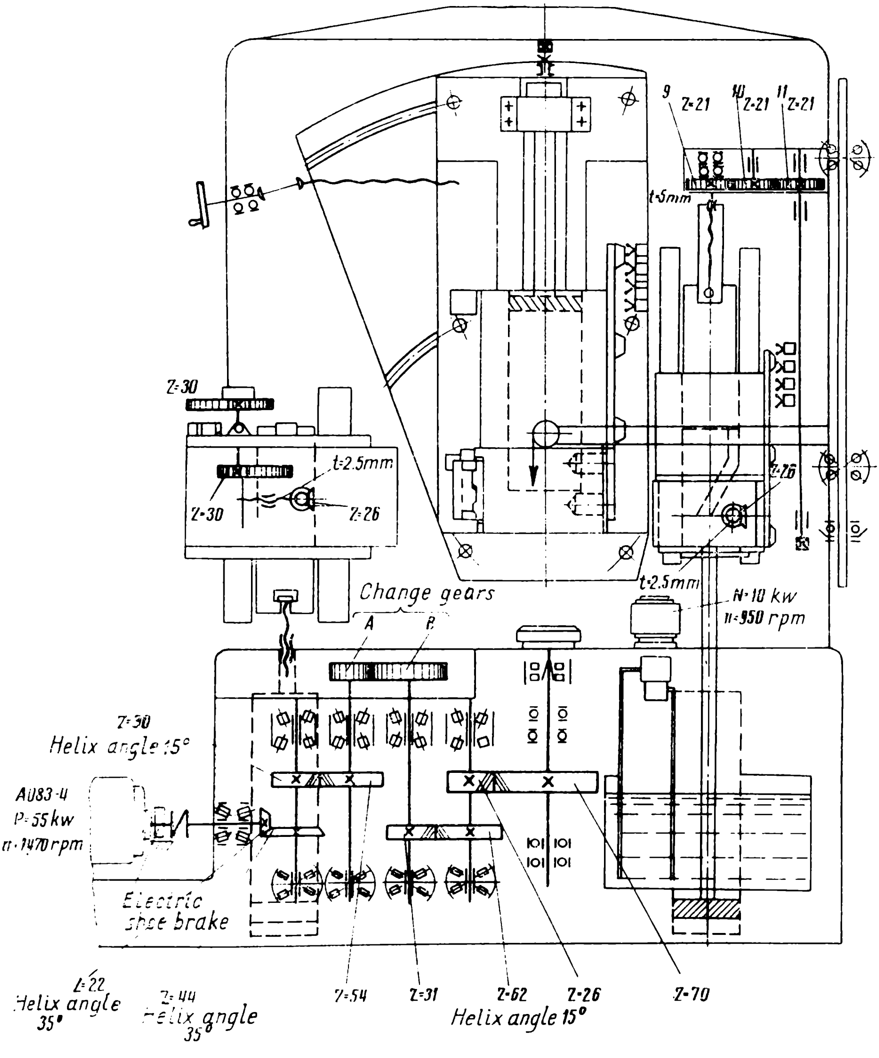


Fig. 163. Gearing diagram of the semi-automatic lathe, model MP4H.

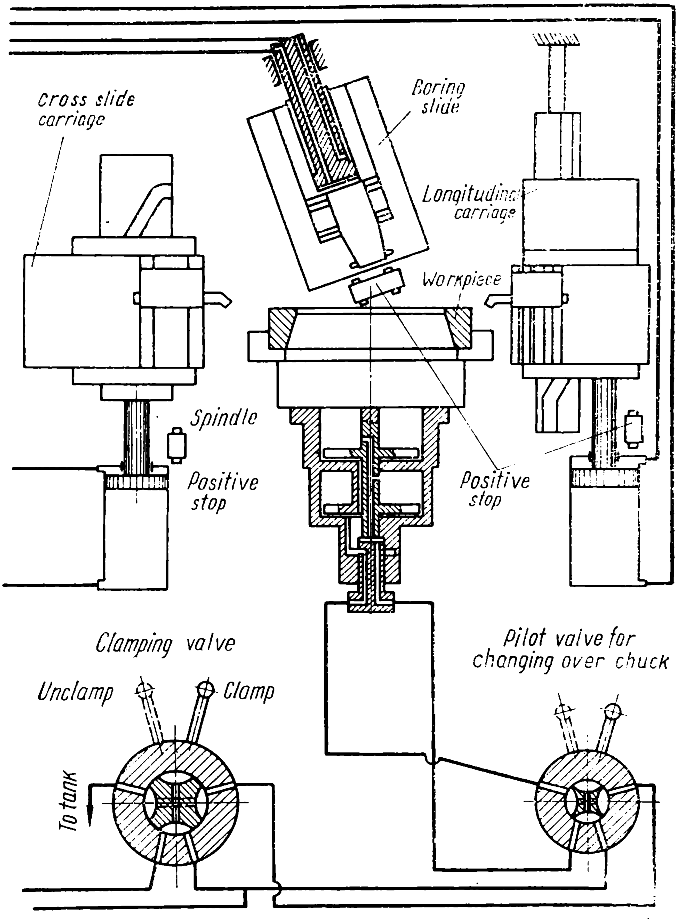
or lower end of the cylinder through the hollow piston rod. As in the other carriages, a bar with trip dogs and limit switches provide for the preset cycle of movements including tool relief.

Tapered holes are bored by setting the boring slide to the required angle and securing it to a plate which may be adjusted vertically. Tapered holes may be bored from the larger to the smaller diameters or in the opposite direction.

The hydraulic drive comprises four independent hydraulic systems — for the longitudinal and cross carriages, the boring slide and the work chucking device. Each hydraulic system is supplied from its own pump unit; the work loading mechanism is supplied from the low pressure pump section of the longitudinal carriage.

The hydraulic systems of each carriage are controlled by solenoids actuating pilot valves. The solenoids are energised by limit switches which are actuated by trip dogs mounted on the carriages.

The hydraulic system operates on the "metering-in" principle with the provision of a special metering channel to ensure constant oil flow, independent of the load, through the throttle valve. This maintains a constant rate of feed.



F i g. 164. Slide travel and work clamping arrangement on the semi-automatic lathe, model MP4H (position shown: "Work clamped" but slides are still in initial positions).

CHAPTER IV

MULTIPLE-SPINDLE AUTOMATIC BAR AND CHUCKING MACHINES

§ 97. MACHINING SEQUENCE

The machining methods employed on multiple-spindle lathes depend on their principle of operation and on the type of blank used.

Work is machined on multiple-spindle single position (parallel-action) automatics in the same way as on single-spindle automatic cutting-off machines (see Fig. 14). Each workpiece is completely machined in a single position on these automatics.

Multiple-spindle single-position vertical semi-automatics are usually of the continuous type (see Fig. 24). The work is loaded and unloaded on each spindle while the other spindles are in operation.

When using a multiple-position progressive-action bar or chucking machine, the work to be done is divided so that a part is done at each position. Each workpiece is machined progressively in station after station and then is removed (automatically or by hand) (see Fig. 20).

The work may be indexed to the next station or position only after machining is finished at each position and the operative units, carrying the cutting tools, have been withdrawn from the work.

This condition stipulates the main rule for selecting the machining sequence for multiple-position lathes, which is: *the most expedient machining method and sequence will be one in which the times required are the same and are a minimum value at each position.*

Since it is difficult to divide the work into operation elements requiring exactly equal machining times, there will always be one position requiring maximum time. This position determines the rate of production of a multiple-spindle progressive-action lathe.

It is evident that in machining work in which one or several operation elements are particularly long, it will be advisable, when possible, to divide such elements between two or more positions. This may reduce the time required on the limiting position and, consequently, increase the rate of production.

Most models of multiple-spindle horizontal automatics and semi-automatics have the same spindle speed for all the positions for a given setup. Therefore, the cutting speed must be selected for that operation element that limits an increase in spindle speed.

Machining operations which require much higher or lower cutting speeds than the others (such as cutting thread, reaming, etc.) are usually performed with supplementary rotation of the attachment or auxiliary tool spindles.

The same is true of the rate of feed of tools mounted on toolslides having a single feed value. In this case, independent-feed toolslides are applied. Optimum cutting speeds and feeds may be obtained for each position on models in which each position has its independent setup speed and feed.

This feature is inherent to multiple-spindle vertical chucking machines.

Multiple-position machining allows the positions, where only roughing is performed, to be separated from those for finishing.

The finished workpiece is usually cut off in the last position on automatic bar machines of the progressive-action type. Stock feed and chucking take place at the same position. *In multiple-spindle progressive-action semi-automatics, the cycle time (or floor-to-floor time) cannot be less than the time required for unloading the finished workpiece, loading and clamping a new blank, and engaging spindle rotation in the loading position.*

The second rule for planning the machining sequence of progressive-action lathes is that *the layout must provide for the simplest and most reliable tooling, all other things being equal.* The use of complex tools, requiring prolonged setting-up time and frequent adjustments, and the use of combination holders, which determine the final size of the work, may be justified only if simpler tools do not enable the work to be completely machined or if they lower the rate of production.

On some of the newer models of Soviet multiple-spindle automatics and semi-automatics, certain workpieces may be completely machined using only a part of the available positions. Then the remaining positions may be used for producing another workpiece. Thus, comparatively simple work may be machined on multiple-spindle bar and chucking machines by the double-flow (or more precisely, double-indexing) method (see Fig. 20).

Six- and eight-spindle automatic bar and chucking machines may operate on this principle. In this case of double-indexing, the spindle carrier indexes through twice as large an angle as in single indexing and each spindle stops only at every other position. Two sets of tooling are provided at adjacent stations and two workpieces are finished in each cycle instead of one.

The manufacturing sequence is planned for double-indexing in the same manner as for single indexing. If two different workpieces are to be made simultaneously:

1) the total machining time for two workpieces must be the same or very near the same;

2) cutting speeds and feeds must not differ considerably;

3) the heaviest machining operations must be performed by the most rigid toolslides.

The cutting speeds and feeds for multiple-spindle bar and chucking machines are based on the operation performed, the workpiece material, tool material, and the specified accuracy and surface finish. The tool life should be at least four hours.

The cutting speeds and feeds used in multiple-spindle bar and chucking machine operation have sharply increased with the application of cemented carbide-tipped tools. They should be selected in accordance with up-to-date handbook data (see also Tables 5 and 6 and § 52).

A large number of cutting tools operate at the same time in any multiple-spindle setup. Consequently, efforts must be made: 1) to balance the cutting forces, 2) to overlap working and idle movements, 3) to apply preset tooling, which enables settings to size to be made before installing the tools, 4) to use standard tools, 5) to use available cams and other tooling elements, so that new ones need not manufactured.

§ 98. FEATURES OF MULTIPLE-SPINDLE BAR MACHINE SETUPS

The most widely used range of bar stock sizes on multiple-spindle automatics is from 16 to 60 mm. Pipe stock from 80 to 125 mm in diameter and even larger is used as well.

Typical work produced on bar-type automatics is illustrated in Fig. 165.

External surfaces are turned from the side or end toolslides. Central holes are machined by tools from the end toolslide.

Thread may be cut by tools mounted on the end toolslide (solid taps and dies, self-opening die heads and collapsing taps) or by others mounted on the side toolslides(threading rolls, chasers, single-point threading tools, etc.). Power feed of the tool of the first group is used only to start the thread. Self-opening die heads are to be preferred for cutting external thread.

The finished work is cut off by a tool in one of the side toolslides.

Standard types of toolholders employed for multiple-spindle bar and chucking machines are illustrated in Table 24.

External surfaces are turned with form tools from the side toolslides in the following cases:

1) when the length of the formed surface is not too large;

2) when accurate lengths and diameters and a good surface finish are required;

3) when it is impossible to machine the surface by tools on the end toolslide.

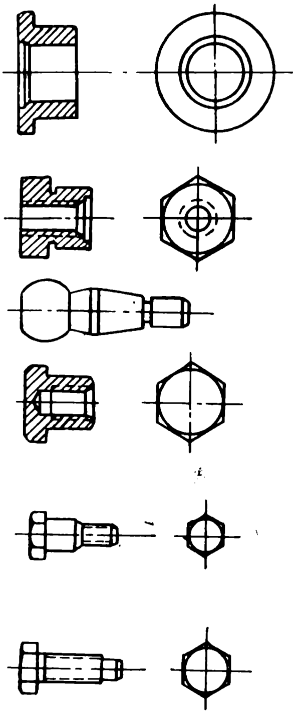
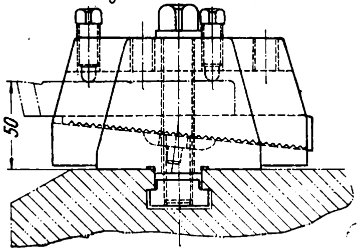


Fig. 165. Typical work machined on multiple-spindle automatic bar machines.

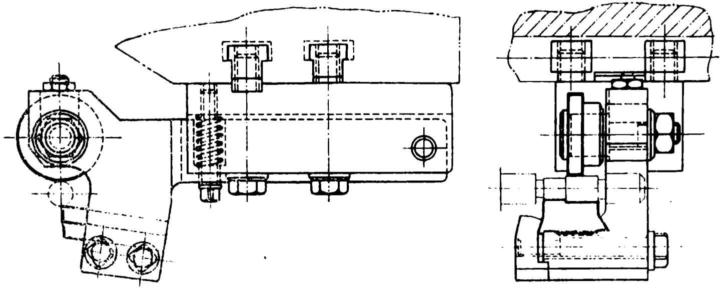
Table 24

Types of Toolholders Used on Multiple-Spindle Automatics

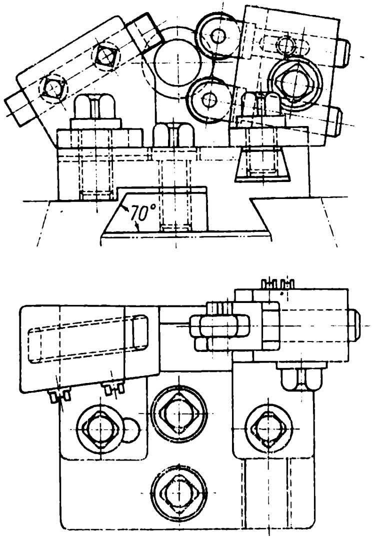
Facing tool holder

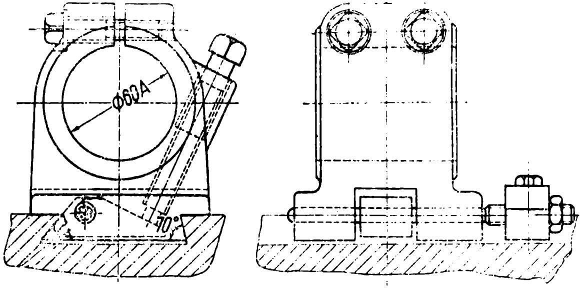


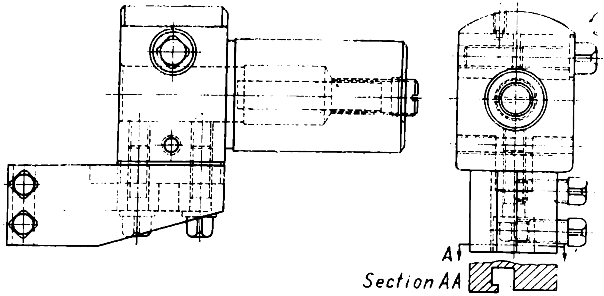
Shaving tool holder



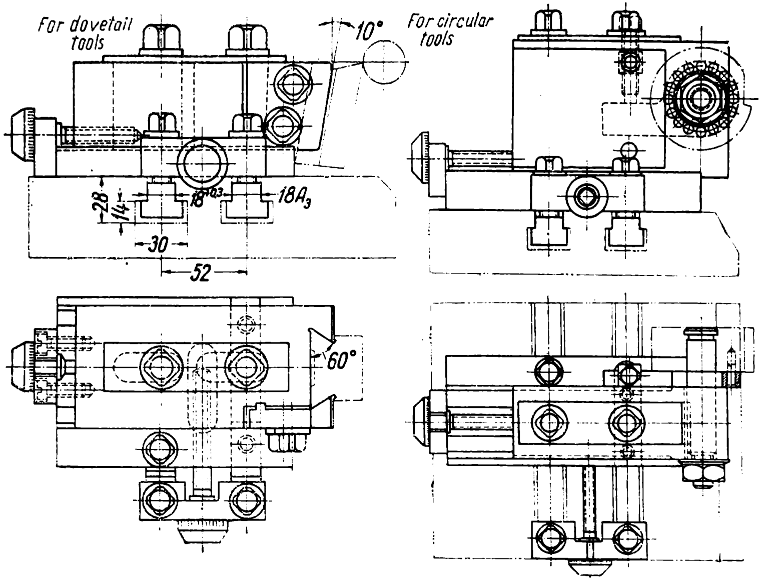
Roll turner of end toolslide



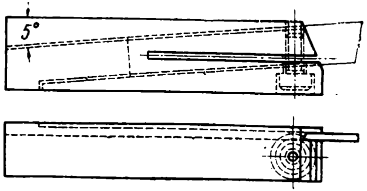




Forming toolholders


For dovetail tools
For circular tools

Cut-off toolholder



Holes are finished by one or two tools in accordance with the accuracy specified.

The drilling of deep accurate holes is to be divided between two or three positions with subsequent machining to the full depth with a core drill and reamer.

Stepped holes are most efficiently machined by first drilling the larger diameter and then the next smaller diameters. Thus, the machining length is divided between several positions.

Spot drilling is desirable before all drilling operations and especially when comparatively deep holes of small diameter are drilled. Spot drilling is also used in cases of a heavy cross load since the large diameter spot drill serves as a supporting centre. In drilling large-diameter through holes, drill travel is increased somewhat so that the next workpiece is spot drilled at the end of the drill travel. Internal recesses are turned with supplementary cross movement of the tool.

It is frequently necessary to face the front end of work on multiple-spindle bar automatics. Otherwise, due to rebound of the bar stock when it strikes the stop in feeding out, the workpiece length may vary from 0.5 to 1 mm. Facing should be performed before the cross-section (and rigidity) of the bar is reduced by any appreciable extent, i.e., in the first positions. If these positions cannot be so employed then a back rest should be applied. Facing and chamfering should be performed by tools in the side toolslides but the end toolslide may also be used for this purpose.

Tooling layouts for a four-spindle automatic are shown in Figs. 166 and 167. Forming (Fig. 166) is divided between two tools mounted in adjacent positions. This reduces the machining time and improves the surface finish.

Long external surfaces are turned by tools on the end toolslide. This turning is also divided between tools in different positions. Finishing is performed by a single end-working or forming tool. Roller back rests are used for turning accurate surfaces or when the bar extends a long distance from the chuck.

A shaving toolholder (see Table 24) is applied to obtain high precision surfaces. It is a floating finish form tool with a roll support. In operation, the roll and tool, having a set distance between them, move together and pass over the work which comes between them. This tool is capable of holding the work diameter within 0.02 or 0.03 mm.

Division of forming between two tools is illustrated in Fig. 167. The work is turned by end-working tools in the 1st and 2nd positions to facilitate the operation of the form tool in the 3rd position.

It is not expedient to use form tools in the 1st position for square or hexagon bar stock since the tool life will be reduced considerably by the impact load. It is advisable to rough the bar first with an end-working tool in such cases.

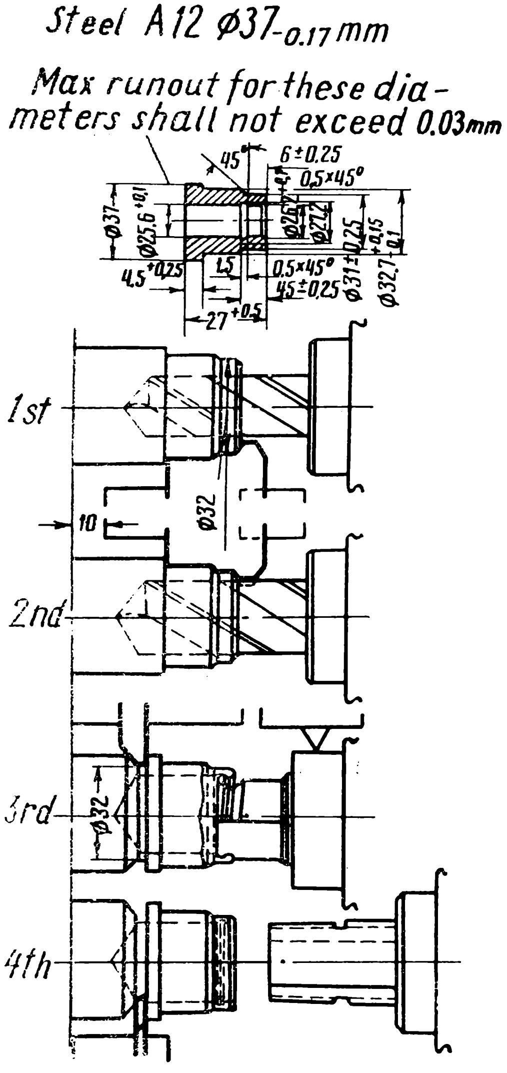


Fig. 166. Tooling layout for a special nut on a four-spindle progressive-action automatic bar machine.

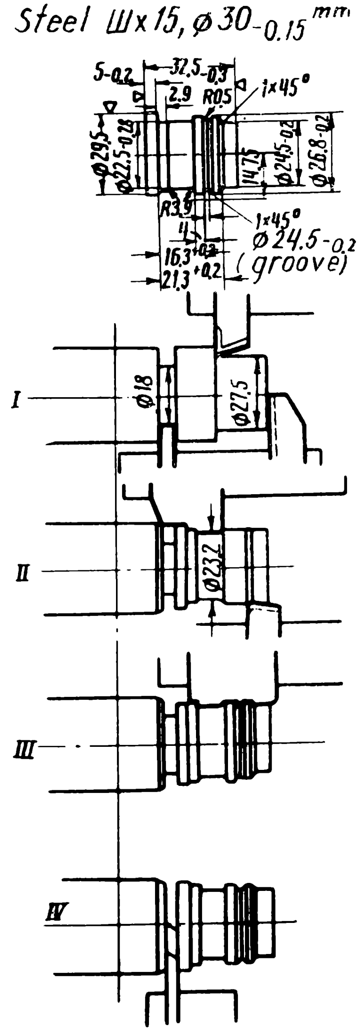


Fig. 167. Tooling layout for a roll on a four-spindle automatic bar machine.

Sometimes long work is produced on multiple-spindle automatics. In this case roll turners are used and the work is supported by a back rest during forming operations.

An example of a tooling layout for a long workpiece is given in Fig. 168. To reduce the overhang to the work, the front end is formed in the 4th position, before feeding out the bar stock. The work is cut off in the 3rd position. A disadvantage of this method is that the steps turned before bar feed may not run true with those turned afterward, due to inaccuracy in chucking the stock.

Form surfaces may also be turned to a template. In this case, the tool is mounted in a special attachment on the end toolslide and the template is in one of the side toolslides. Duplicating is also possible

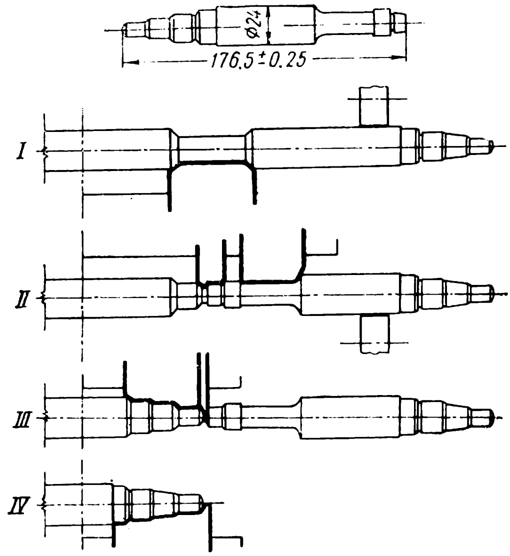


Fig. 168. Tooling layout for a long shaft on a four-spindle automatic bar machine.

with a special attachment mounted on a side toolslide which is traversed by the end toolslide to a template. For comparison, the tooling layout of the same workpiece machined on an ordinary and on a tracer-type automatic is shown in Fig. 169 *a* and 169 *b*, respectively.

Fig. 170 is a tooling layout for a six-spindle automatic and Fig. 171 compares the tooling layouts, designed for the same workpiece, on four- and six-spindle bar automatics.

More complex tools are required to complete the workpiece in four positions. Besides this, the tapered hole cannot be machined with the same accuracy and surface finish as on a six-spindle machine, due to larger number of available tooling positions. If taper reaming in one the position is sufficient, in the second case, then drilling may be divided into four positions to increase the rate of production.

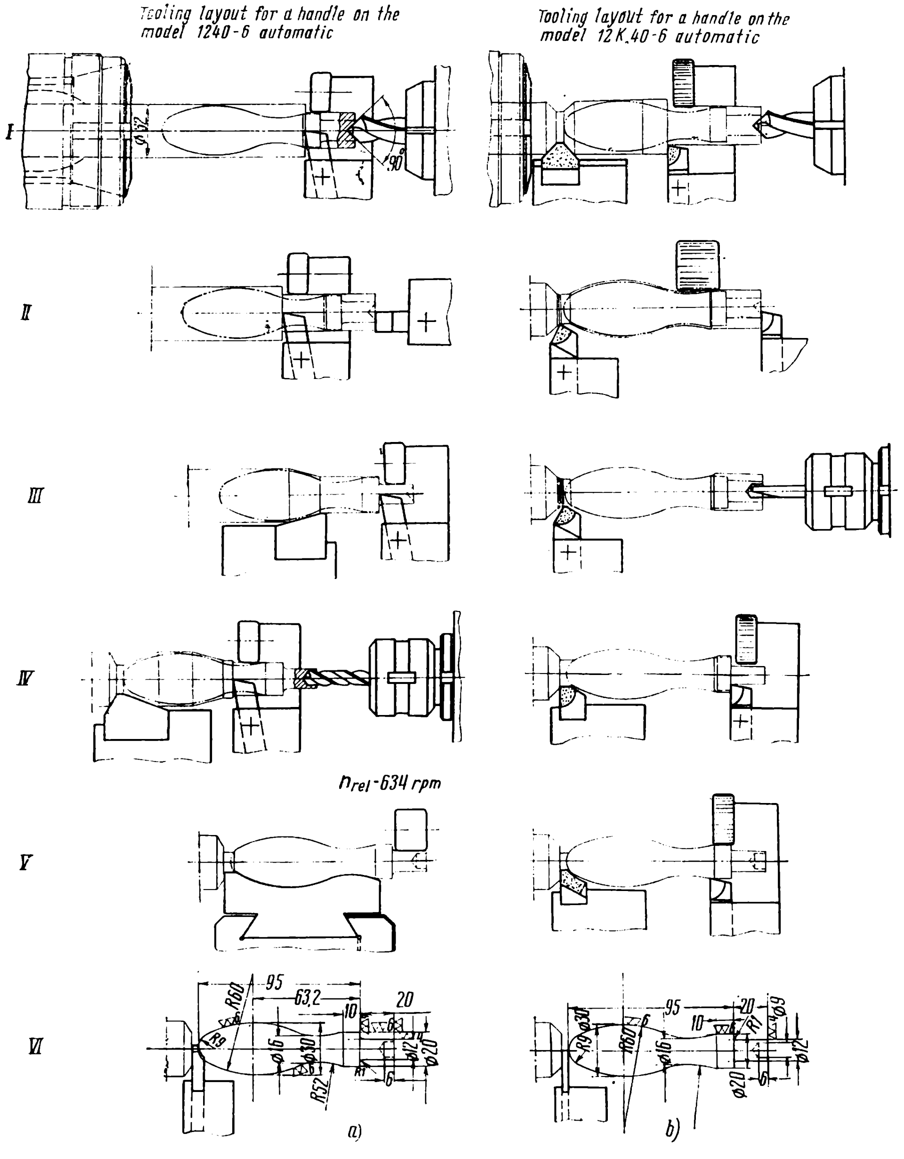

Tooling layout for a handle on the model 1240-6 automatic
Tooling layout for a handle on the model 12K.40-6 automatic
I
φ32
90°
II
III
IV
n_{rel}-634 rpm
V
VI
95
63.2
10
20
R60
R9
φ16
φ30
R52
R1
6
φ12
φ20
a)
95
20
10
R9
φ30
R60
φ16
R1
φ9
φ12
φ20
6
b)

Fig. 169. Tooling layouts for a machine handle on an ordinary (*a*) and a tracer-type (*b*) six-spindle automatic.

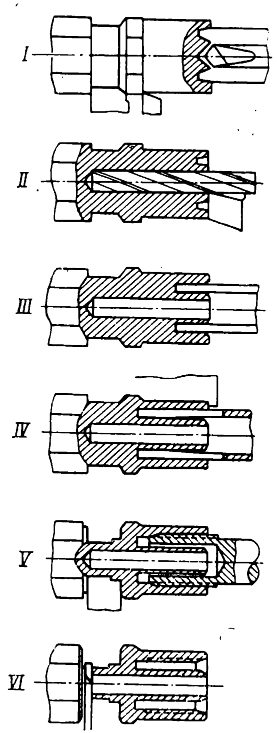
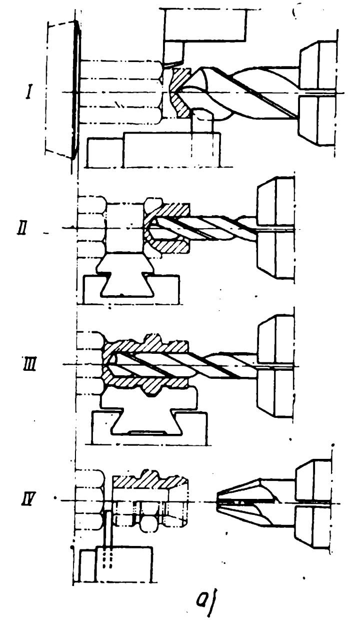


Fig. 170. Tooling layout on a six-spindle automatic.



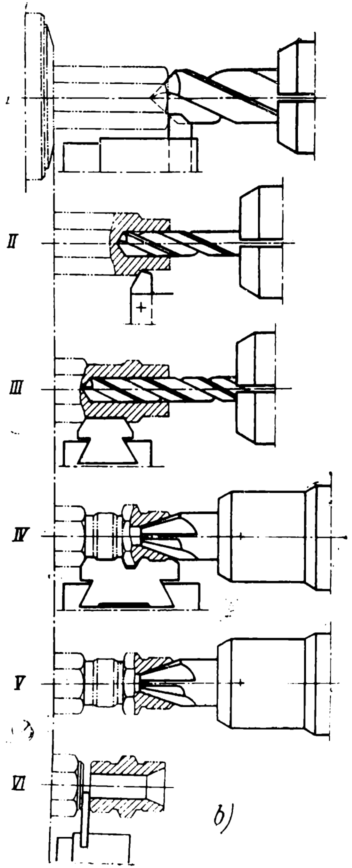


Fig. 171. Tooling layout for a pipe connection on a four-spindle (*a*) and a six-spindle (*b*) automatic.

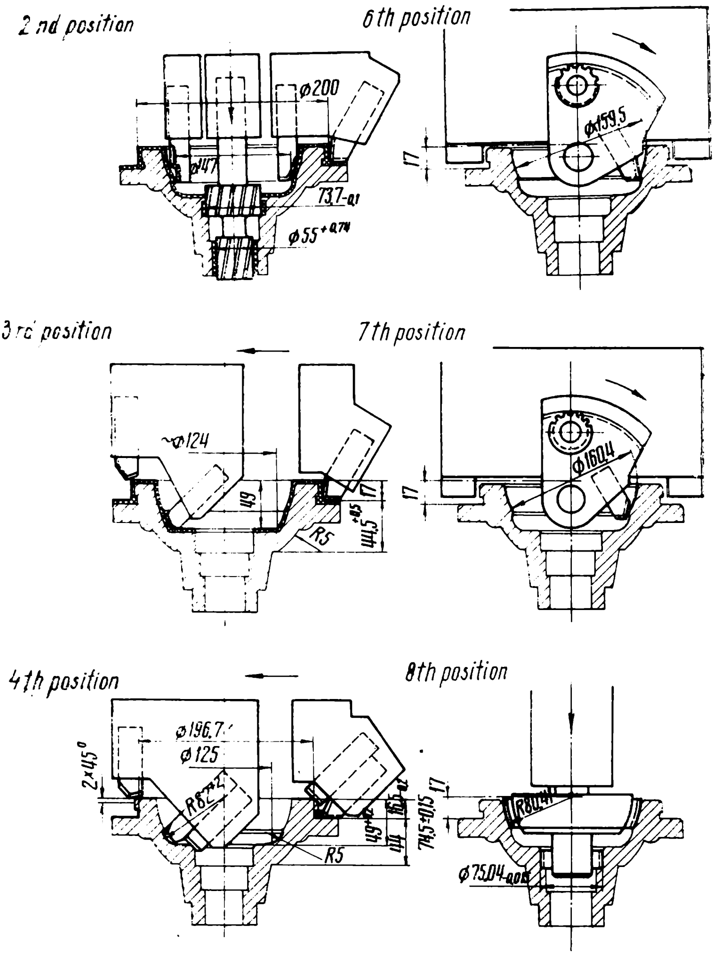


Fig. 172. Tooling layout on a vertical eight-spindle progressive-action semi-automatic lathe.

§ 99. FEATURES OF MULTIPLE-SPINDLE CHUCKING MACHINE SETUPS

Separate blanks (forgings and castings) may be machined on multiple-spindle automatics equipped with magazine-feed divices (see Fig. 81 *d*) or multiple-spindle chucking machines (semi-automatics) with manual loading and unloading.

Two following types of blanks are machined on magazine-feed automatics:

1) work previously machined in an automatic lathe (so-called "second operation" work);

2) blanks, such as precise forgings or die castings.

The machining sequence for magazine-feed automatics is almost the same as for bar-type automatics. As mentioned above, the processing capacity of magazine-feed automatics is somewhat less than of the bar type but it is usually sufficient since the blank has a form nearer to the finished workpiece.

Workpieces that cannot be machined on magazine-feed automatics are machined on multiple-spindle semi-automatics.

The machining sequence differs considerably for the different types and designs of multiple-spindle semi-automatic lathes.

The following factors are of importance in machining separate blanks:

1) the form of the blank is usually near to the form of the finished workpiece and, therefore, less stock is removed than when the work is turned from a bar;

2) separate blanks are usually machined in two settings since the surface used for clamping in the first setting is subsequently machined;

3) separate blanks are usually for large size work and, therefore, larger torques appear than for bar stock.

Multiple-spindle vertical semi-automatic lathes have a considerably larger processing capacity due to their three types of tool heads including the combination type. They can machine work of larger diameter and more complex form than horizontal semi-automatics.

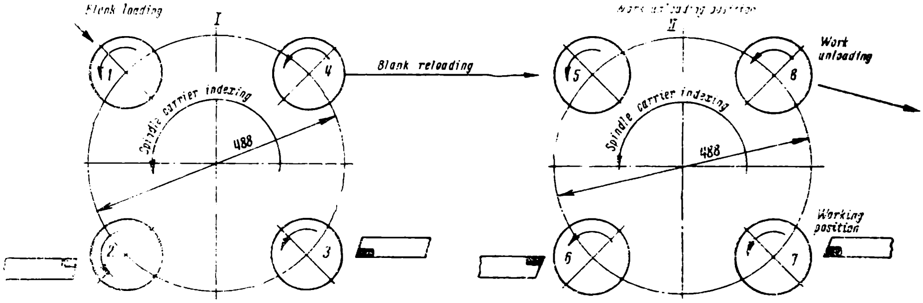


Fig. 173. Turning setup for bearing rings on a two-sided eight-spindle automatic lathe, model СКБ-6.

The machining methods employed are the same for horizontal and vertical multiple-spindle semi-automatics (Fig. 172). Both sides of bearings are machined on the two-sided eight-spindle chucking automatics, model СКБ-6 (Fig. 173).

§ 100. FOUR- AND SIX-SPINDLE BAR AND CHUCKING AUTOMATICS AND SEMI-AUTOMATICS

Brief specifications of these machines are presented in Tables 25 and 26. Though various models of these automatics and semi-automatics are manufactured in different plants, there is much in common between their drives, gear trains, general arrangement, and construction. Setting-up methods are practically the same for all of these models. Multiple-spindle automatic and semi-automatic lathes are high-production machine tools and are designed for large-lot and mass production shops.

§ 101. NEW MULTIPLE-SPINDLE AUTOMATICS AND SEMI-AUTOMATICS

The six-spindle automatic bar machine, model 1A225, is the basic model of a size range in which the maximum bar capacity is 32 mm. As a rule, four-spindle automatics of a unified range have a larger, and

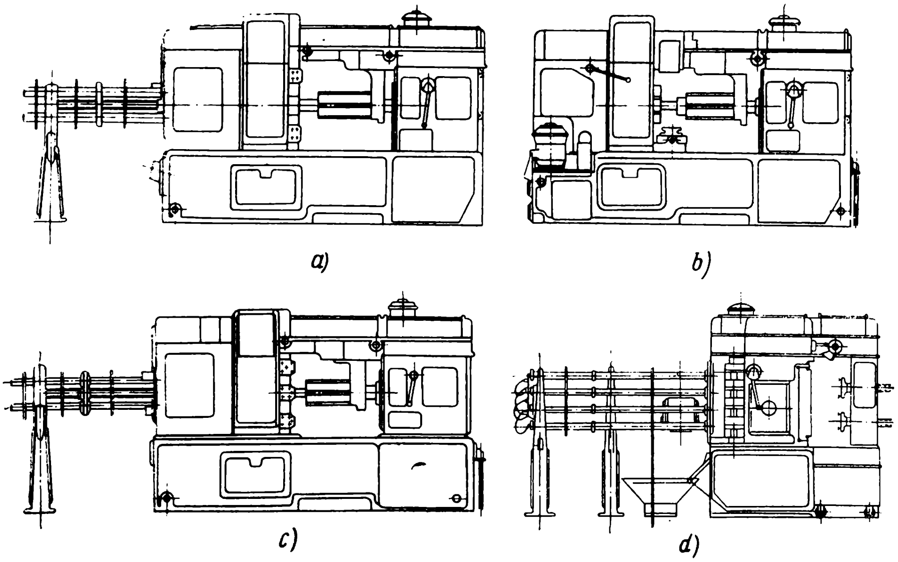


Fig. 174. The 1240 size range of multiple-spindle automatic bar and chucking machines.

a—six-spidle automatic bar machine, model 1240-6, *b*—six-spindle semi-automatic chucking machine, model 1240-6П, *c*—four-spindle automatic bar machine, model 1240-4, and *d*—four-spindle straight (parallel-action) automatic bar machine, model 1240-0.

Table 25

Brief Specifications of Multiple-Spindle Automatic Bar Machines

Item	Unit	Model						
		П1A225—6	1240—4	1240—6	1240—0	1265—4	1265—6	1290
Bar capacity	mm	25	40	40	40	65	65	100
Maximum stock feed	mm	150	200	200	300	200	200	215
Number of side toolslides		6	4	6	2 for each spindle	6	6	4
Number of spindle speeds		24	24	24	20	24	24	24
Range of spindle speeds	rpm	280 to 2,560	156 to 2,120	158 to 2,170	198 to 1,423	79.5 to 1,600	79.5 to 1,600	54 to 737
Range of work spindle revolutions to make one piece	rev		217 to 1,317	217 to 1,317	113 to 1,123	—	—	14 to 1,355
Number of camshaft speeds		24	23	23	24	—	—	—
Time for idle motion of camshaft	sec	2.3	2.7	2.1	1.78	3.5	3.5	5
Main drive motor power (1,450 rpm)	kw	up to 14	up to 20	up to 20	10	28	28	28
Overall dimensions:								
floor space occupied	mm	5,705×1,250	5,810×1,405	5,810×1,405	6,000×1,323	5,330×1,500	5,330×1,500	5,360×1,955
height	mm	1,714	2,055	2,055	1,950	2,070	2,070	2,100
Approximate net weight	kg	6,700	8,700	9,000	4,400	13,000	13,000	17,000

Table 26

Brief Specifications of Multiple-Spindle Semi-Automatic Chucking Machines

Item	Unit	Model		
		1240-6П	1265-II	1290-II
Maximum diameter of chuck accommodated	mm	150	250	300
Maximum diameter machined	mm	120	200	250
Maximum length machined	mm	120	175	200
Number of work spindles	—	6	4	6
Number of side slides	—	5	4	4
Independent-feed tool spindles may be installed in positions		5th and 6th	any	any
High-speed drilling attachment may be installed in positions		any	any	any
Threading attachment may be installed in positions		5th and 6th	3rd and 4th	3rd and 4th
Range of work spindle speeds	rpm	86 to 1,172	58 to 732	41 to 557
Range of work spindle revolutions to make one piece	rev	119 to 1,317	—	14 to 1,356
Time for idle motion of camshaft	sec	2.37	3.5	5
Main drive motor power . . .	kw	14 to 20	20 to 28	28 to 40
Inching drive motor power	kw	1.7	1.7	2.8
Overall dimensions:				
Floor space occupied	mm	3,200×1,540	3,400×1,720	3,900×1,955
height	mm	1,960	2,100	2,100
Approximate net weight . . .	kg	9,000	12,500	16,000

eight-spindle models, a smaller bar capacity than the basic six-spindle machine.

The type 1240 size range (Fig. 174) has been extensively developed. It includes four- and six-spindle automatics and a six-spindle semi-automatic. Models 1240-0, 1240-4, and 1240-6 are automatics with a bar capacity of 40 mm. These are high-speed machine tools that effectively employ cemented carbide-tipped tools. Motors up to 20 kw may be installed in their main drives.

These new models have the following advantageous features in comparison with earlier models:

1) considerable reduction in setting-up time due to the application of constant toolslide and tool spindle cams, as well as to the provision of a cycle indicator and a special electric motor for turning over (inching) the camshaft in setting up;

2) more convenience in setting up tool spindles (as differing from previous models, this may be done without disassembling the drive);

3) more ease in setting up due to the micrometric screws in the side toolslide toolholders;

4) simpler handling since the automatic may be restocked either behind or in front of the stock reel;

5) improved chip disposal facilities; an important feature for high-speed machining;

6) more safety features including protection against the rotating bar stock, impossibility of starting the main drive motor during restocking or when setting speeds or feeds, and the impossibility of accidental engagement of high-speed camshaft rotation.

§ 102. SIX-SPINDLE AUTOMATIC BAR MACHINE, MODEL 1240-6

General Arrangement. This automatic is of frame-type construction (Fig. 175) in which the top brace connects the headstock and gearbox mounted at the right and left sides of the heavy base.

The base also serves as a reservoir for cutting fluid and lubrication oil. The chip conveyer is located in the central opening of the base. The gearbox is mounted on the right-hand side of the base. The headstock and rear support, two housings, are mounted, one after the other, at the left.

The headstock has a central bore for the spindle carrier with the work spindles. The headstock also carries the carrier locking mechanism and levers and tie-rods for actuating the side toolslides.

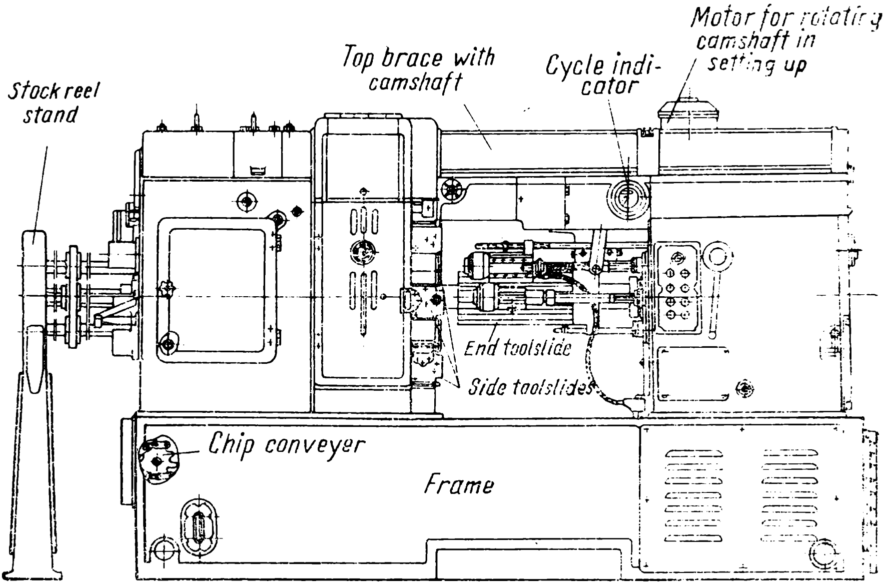


Fig. 175. Six-spindle automatic bar machine, model 1240-6.

Four bronze shoes on the rear wall of the headstock prevent axial movement of the carrier.

The rear support housing contains the stock feeding and chucking mechanism, as well as the carrier lifting and indexing arrangements.

The stock reel with the stock tubes is located at the left beyond the rear support. The top brace, on top of the headstock and gearbox, makes up the rigid box-type frame. The top brace houses the camshaft, running in ball bearings and carrying drums and discs on which cams are fastened.

Six slot-type side toolslides are provided on the six-spindle model and four on the four-spindle automatic. The side toolslides travel in ways attached to the front end wall of the headstock.

The end toolslide is of the central type. It travels on a stem press-fitted in the carrier. The end toolslide is held against rotation by a guide arm which travels on ways under the top brace.

The flat surfaces of the end toolslide have dovetail slots for clamping rigid toolholders guiding independent-feed toolholders.

The gear trains of the automatic are based on the centralised drive principle (Fig. 176); only the inching rotation of the camshaft for setting up and the chip conveyer are driven from separate motors.

The work spindles are driven from the main drive motor through V-belts, change gears, sliding gears, constant gearing (45T. : 45T.), the central gear and the spindle gears.

The setting up formula for work spindle speeds is:

$$n_s = n_m \times \frac{A}{B} \times i_v \times C \text{ rpm}$$

in which $\frac{A}{B}$ is the gearing ratio of the change gears;

i_v is the gearing ratio of the sliding double cluster gear

$$\left(i_{v_1} = \frac{25}{67} \text{ and } i_{v_2} = \frac{55}{37}\right);$$

C is the gearing ratio of all constant gearing in the main drive train.

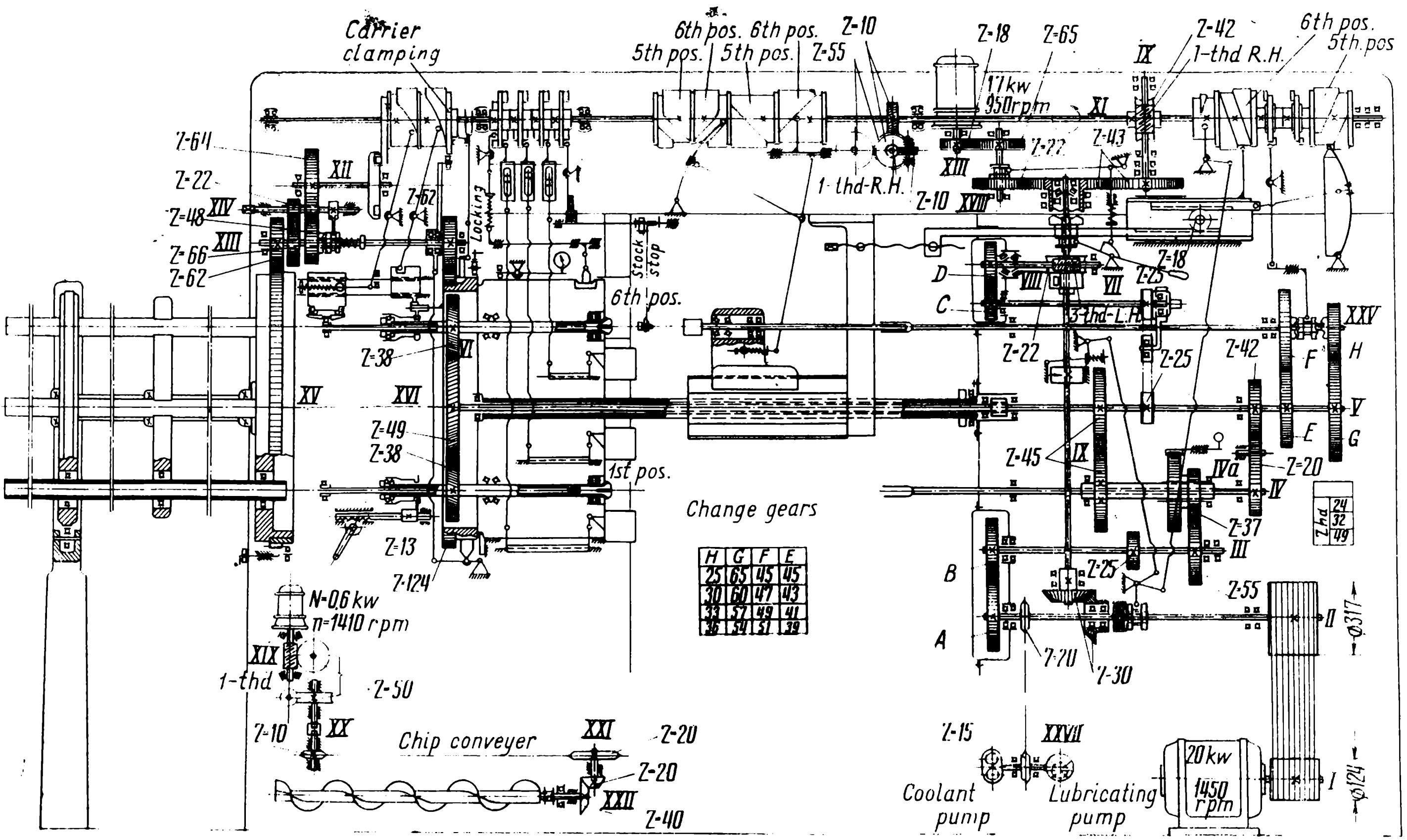
The following formulas are used in selecting the spindle speed change gears:

$$\text{for } i_{v_1} = \frac{25}{67} \quad \text{for } i_{v_2} = \frac{55}{37}$$

$$\frac{A}{B} = \frac{n_s}{220} \qquad \frac{A}{B} = \frac{n_s}{878}.$$

The drive for the high-speed drilling attachment spindles (Fig. 177) is taken off the central shaft. These spindles rotate in a direction opposite to work spindle rotation. The speed of the drilling attachment spindles will be:

$$n_{hd} = n_s \times \frac{32.57}{Z_{hd}} \text{ rpm}$$



H	G	F	E
25	65	45	45
30	60	47	43
33	57	49	41
36	54	51	39

Z hd	24
	32
	49

a)

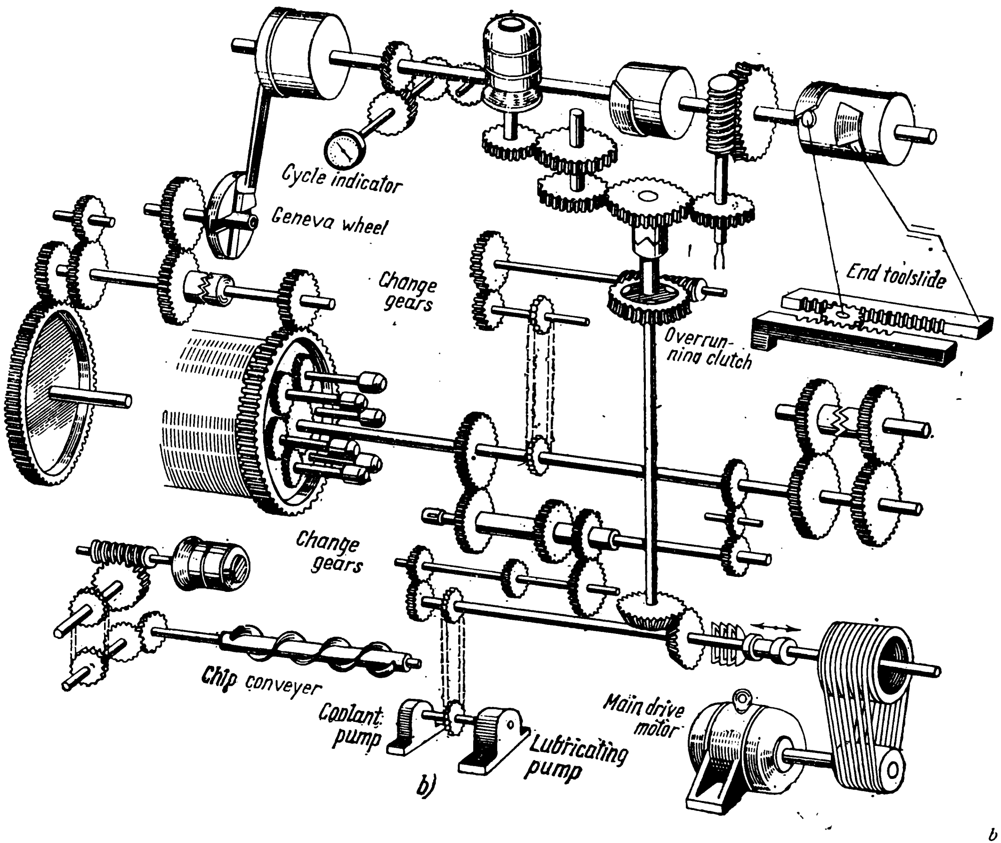


Fig. 176. **Six-spindle automatic bar machine, model 1240-6.**

a -- line gearing diagram with gearing elements indicated.

$$n_{s_I}=1,450\times\frac{124}{317}\times\frac{A}{B}\times\frac{25}{67}\times\frac{45}{45}\times\frac{49}{38}\ \text{rpm};$$

$$\frac{A}{B}=\frac{n_{s_I}}{220}$$

$$n_{s_{II}}=1,450\times\frac{124}{317}\times\frac{A}{B}\times\frac{55}{57}\times\frac{45}{45}\times\frac{49}{38}\ \text{rpm};$$

$$\frac{A}{B}=\frac{n_{s_{II}}}{878}$$

$$n_{h\,d}=n_s\frac{42}{20}\times\frac{20}{Z_{h\,d}}\ \text{rpm};$$

$Z_{h\,d}=24$, 32, and 49 teeth.

$$n_{th}=n_s\times\frac{38}{49}\times\frac{E}{F}\ \text{or}$$

$$n_{th}=n_s\times\frac{38}{49}\times\frac{G}{H}\ \text{rpm};$$

$$n_{cs\,(w)}=n_s\times\frac{25}{25}\times\frac{C}{D}\times\frac{3}{22}\times\frac{43}{43}\times\frac{1}{42}\ \text{rpm}$$

$$n_{cs\,(h\,s)}=1,450\times\frac{124}{317}\times\frac{30}{30}\times\frac{43}{43}\times\frac{1}{42}\ \text{rpm}.$$

b -- isometric gearing diagram.

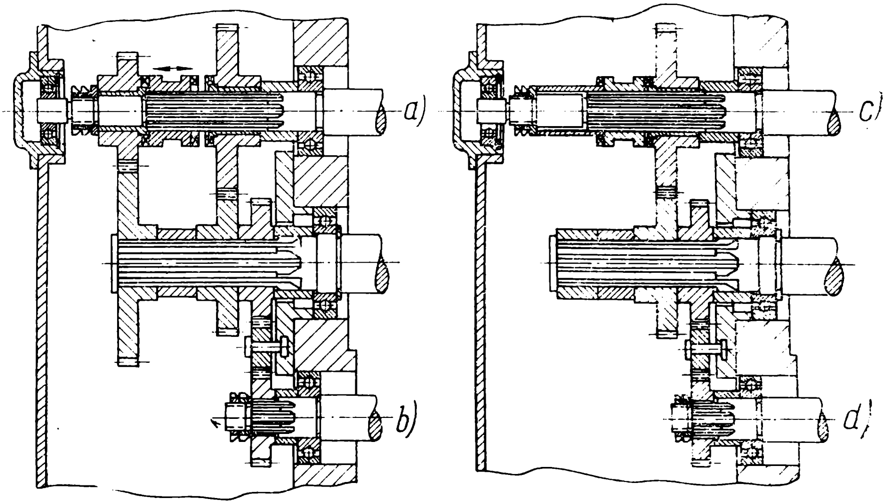


Fig. 177. Tool spindle drive for the model 1240-6 automatic.
a—for cutting thread with a solid tap or die, *b* and *d*—for high-speed drilling, c—for cutting R. H. thread with a self-opening die head and for reaming.

in which Z_{hd} is the number of teeth on the gear mounted on the attachment spindle.

This formula can be rearranged to select the gear on the attachment spindle:

$$Z_{hd} = 32.57 \frac{n_s}{n_{hd}} \text{ teeth.}$$

Since the drilling attachment and work spindles rotate in opposite directions, drilling will be performed at a cutting speed depending on the relative speed of the attachment spindle:

$$n_{hd-rel} = (n_s + n_{hd}) \text{ rpm.}$$

Example: Set up the gear train of the high-speed drilling attachment drive on the model 1240-6 automatic to drill a hole with a drill $d_d=8$ mm at a cutting sqeed of 31.4 m per min. The spindle speed $n_s=500$ rpm.

First, the relative speed is determined for which the 8 mm drill will have a cutting speed of 31.4 m per min:

$$n_{hd-rel} = \frac{1{,}000v}{\pi d_d} = \frac{1{,}000 \times 31.4}{3.14 \times 8} = 1{,}250 \text{ rpm.}$$

The speed of the drilling attachment spindle is determined by the formula:

$$n_{hd-rel} = n_s + n_{hd},$$

then $1{,}250 = 500 + n_{hd}$; $n_{hd} = 1{,}250 - 500 = 750$ rpm.

Therefore: $Z_{hd}=32.57\frac{n_s}{n_{hd}}=32.57\frac{500}{750}\approx 22$ teeth.

However, the gears available on the automatic have $Z_{hd}=24$, 32, and 49 teeth and therefore the nearest gear to the computed value is selected: $Z_{hd}=24$ teeth. The actual speed of the attachment spindle will then be:

$$n_{hd}^{a}=32.57\frac{n_s}{24}\approx 679 \text{ rpm}.$$

This will give an actual relative speed of:

$$n_{hd-rel}^{a}=500+679=1{,}179 \text{ rpm}$$

and an actual cutting speed of:

$$v^{a}=\frac{\pi d_d \times n_{hd-rel}^{a}}{1{,}000}=\frac{3.14\times 8\times 1.179}{1{,}000}\approx 29{,}6 \text{ m per min.}$$

Consequently, the drilling will be performed with a cutting speed of $v^{a}=29.6$ m per min instead of $v=31.4$ m per min given in the example.

Thread may be cut either with a self-opening die head (Fig. 177 *c*) or with a solid tool (tap or die) by the overrunning method (Fig. 177 *a*).

In cutting thread with a self-opening die head, rotation is also obtained from the central shaft.

The threading attachment spindle rotates in the same direction as the work spindle. The attachment is set up on the basis of the given threading speed v_{th}, the work spindle speed n_s, the threading spindle speed n_{th}, and the relative speeds of the work and threading spindles:

$$n_{th-rel}=n_s-n_{th} \text{ rpm},$$

$$n_{th-rel}=\frac{1{,}000 v_{th}}{\pi d_{thread}} \text{ rpm}, \quad n_{th}=n_s\frac{38}{49}\times i_{ch.gears}.$$

When thread is cut by the overrunning method (with a solid tap or die), provision must be made for advancing the tool at the threading spindle speed n_{ad} and for backing the tool off or out at the speed n_{bo}. Threading spindle speeds are changed automatically by the shifting of a clutch. The setting-up formulas are the same as for threading with a self-opening die head.

All working and idle movements are obtained from the central camshaft. The camshaft rotates at a slow working speed set up by change gears and at a constant high speed, independent of the setup, for idle motions. Slow working rotation of the camshaft is obtained from the central shaft and is set up by the following formula:

$$\frac{\alpha_w}{360}\times\frac{42}{1}\times\frac{43}{43}\times\frac{22}{3}\times\frac{D}{C}\times\frac{25}{25}\times\frac{49}{38}=n_o$$

in which α_w is the angle of camshaft rotation required for the longest operation element;

n_o is the number of spindle revolutions required for the longest operation element.

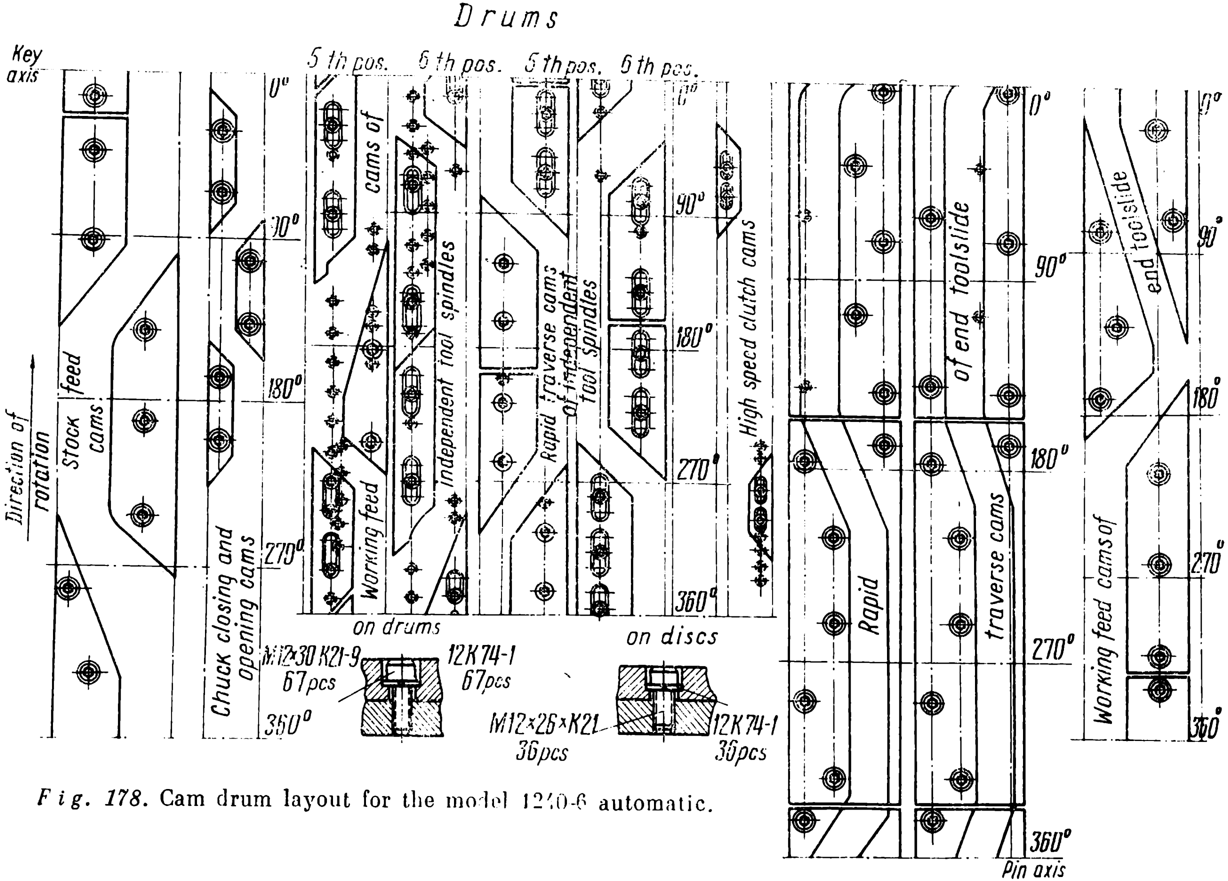


Fig. 178. Cam drum layout for the model 1240-6 automatic.

The following formula serves to compute the change gears for slow camshaft speed:

$$\frac{C}{D}=\frac{C}{n_o} \text{ in which } C=\frac{\alpha_w}{360}\times\frac{42}{1}\times\frac{43}{43}\times\frac{22}{3}\times\frac{25}{25}\times\frac{49}{38}.$$

High-speed rotation of the camshaft is obtained from the first drive shaft through the overrunning clutch in the smaller worm wheel:

$$n_{cs\,(h\,s)}=n_m\times\frac{124}{317}\times\frac{30}{30}\times\frac{43}{43}\times\frac{1}{42}\text{ rpm.}$$

The idle time (time for high-speed camshaft rotation) is determined by the formula:

$$t_i=\frac{60}{n_{cs\,(h\,s)}}\times\frac{360-\alpha_w}{360}\approx 2.1\text{ sec.}$$

A band brake on the vertical drive shaft prevents an impact at the moment high-speed camshaft rotation is engaged.

The general formula, for setting up the feeds of all toolslides, is:

$$s=i_{s-cs}\times\pi D\tan\beta i_{sl}\text{ mm/rev}$$

in which $i_{s-cs}=\frac{38}{49}\times\frac{25}{25}\times\frac{C}{D}\times\frac{3}{22}\times\frac{43}{43}\times\frac{1}{42}$ and is the gearing ratio of the train from the work spindles to the camshaft;
D is the cam drum diameter in mm;
β is the helix angle of the cam rise;
i_{sl} is the ratio of the lever system from the camshaft to the toolslide.

The camshaft is rotated for setting up from a separate motor with an "inching" push button. The camshaft rotates only while the button is held down.

The coolant and lubricating pumps are driven through a chain from the first shaft of the gearbox. The screw-type chip conveyer is powered from a separate motor through transmission with a total gearing ratio $i=\frac{1}{200}$.

Two compartments with change gears for setting the required work spindle and camshaft speeds are arranged on the front face of the gearbox. The ends of the power drive tool spindles are also arranged here.

Built-in push button stations for controlling all the motors on the automatic and a lever controlling the camshaft drive are duplicated on both the front and rear walls of the gearbox.

The gearing diagrams for the other models in the size range of multiple-spindle automatics differ very little from those of the six-spindle model presented in Fig. 176.

The *cyclogram* of automatic lathe operation (see Fig. 69) is based on the principle of performing all working travel during the time the camshaft rotates through 130° or 140°. All idle motions take up 230°

or 220° of high-speed camshaft rotation. A small angle (3° to 4.5°) of slow (working) rotation of the camshaft is reserved for disengaging the rapid traverse clutch.

Construction Features. A hollow stem, press-fitted into the spindle carrier (Fig. 180), contains the shaft driven from the gearbox and transmitting rotation to the work spindles.

The spindles in the carrier run in two supports. The front support comprises a double-row roller bearing with a tapered bore, while the rear support consists of angular contact ball bearings. The front and rear bearings are adjusted by nuts. The roller-type chucking sleeves are mounted in the left end of the spindles.

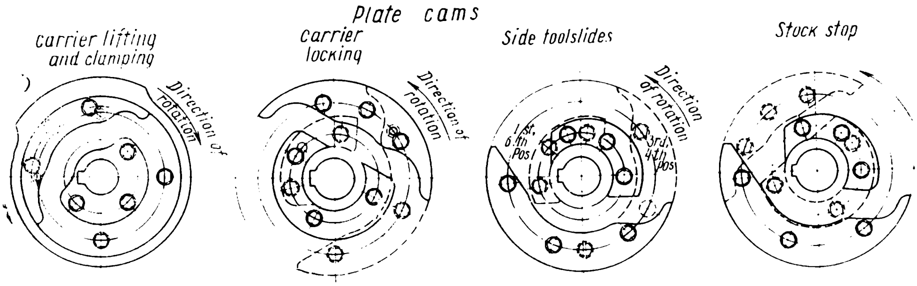


Fig. 179. Plate cam layout on the drums of the model 1240-6 automatic.

The hollow work spindle contains the collet tube with the spring collet on one end and an adjusting nut on the other, as well as the stock feeding or pusher tube with the pusher. A collar, with a bearing by which the stock feeding mechanism engages the pusher tube, is mounted on the left end. A guide bushing for supporting the bar stock is inserted in the pusher tube collar.

Before indexing, the spindle carrier is automatically lifted slightly (0.3 or 0.4 mm) above its locating surfaces by means of the lever mechanism shown in Fig. 181. Carrier lift is checked by an indicator with a hand. The carrier is indexed by a Geneva wheel operated from an indexing arm on the camshaft.

Segment gears, controlling the positive stops of the side slides, are attached to the carrier.

The spindle carrier is locked (Fig. 181 *a*) by two locking levers *1* and *9*. Lever *1* serves as a positive stop in locking seat *4* and locates the carrier. The second lever *9* bears against another locking seat and forces the carriage to seat against lever *1*.

In the operation of the locking mechanism, after indexing the carrier, cam *5* on the camshaft actuates lever *6*, which swivels lever *10* through tie-rod *7* and spring *8*. Through shaft *11*, lever *10* swivels lever *12* on which lever *8* and tie-rod *3* are pivoted. Upon rotation of lever *12*, tie-rod *3*, through spring *2*, swivels lever *1* into the locking

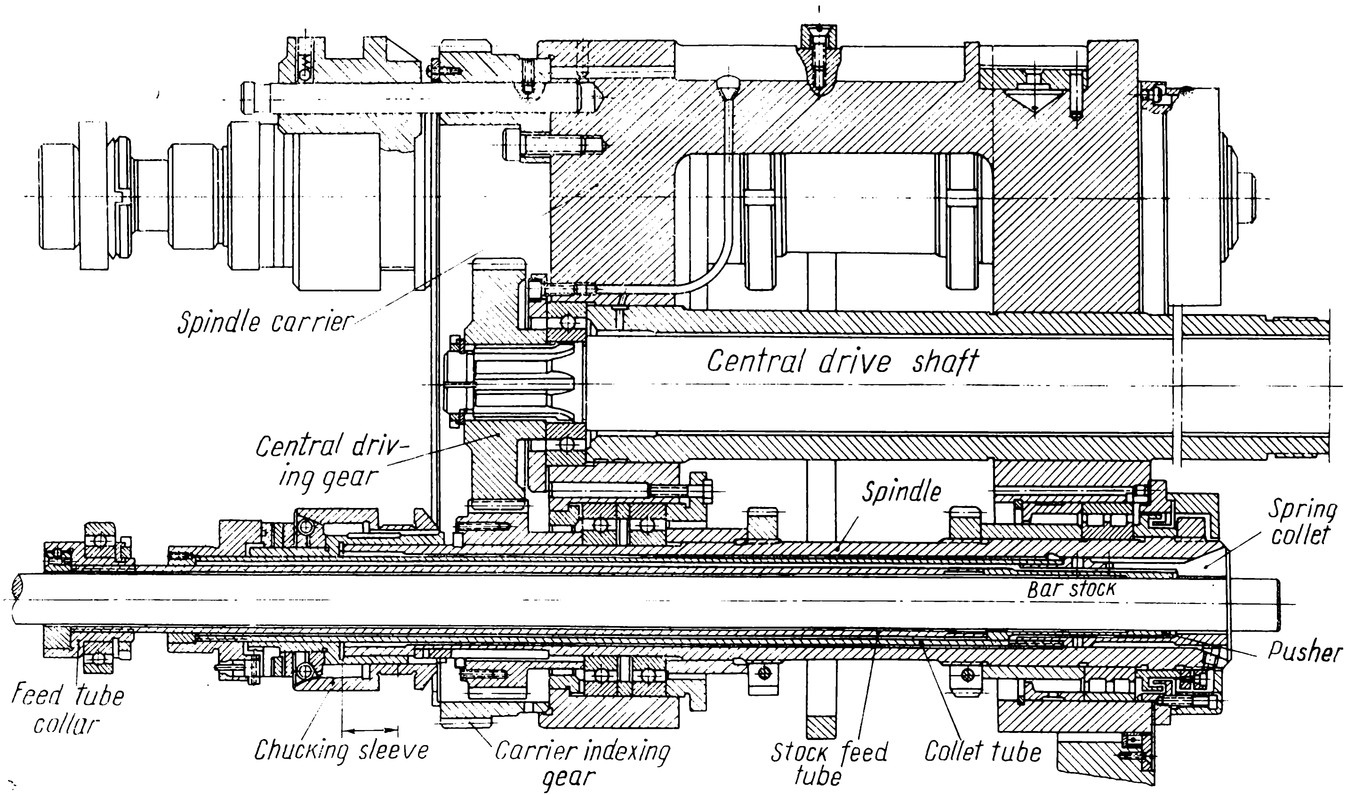


Fig. 180. Section through the spindle carrier of the model 1240-6 automatic.

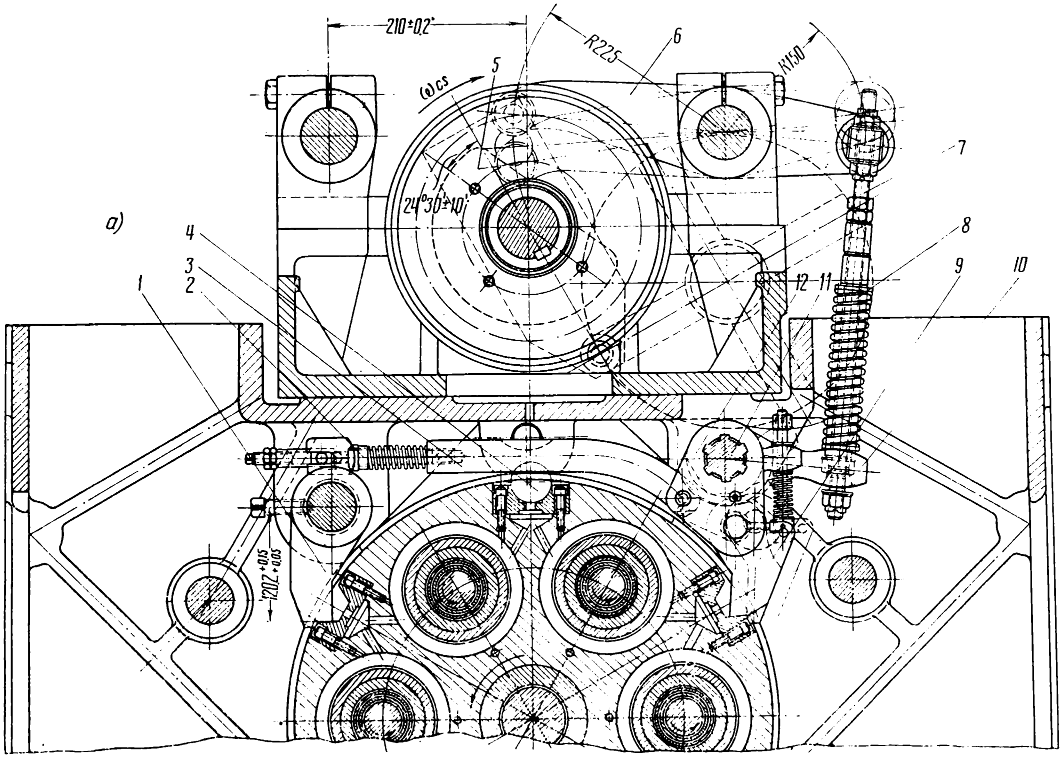


Fig. 181a. Cross-section through the spindle carrier of the model 1240-6 automatic.
a—construction.

seat of the carrier. Further rotation of lever *12* will swivel lever *9* into another locking seat. The force of the locking spring *8* is multiplied several-fold due to the knuckle action in the link between levers *9* and *12*. When tie-rod *7* is raised, the spindle carrier is unclamped. The carrier has an additional clamping device (Fig. 181 *c*) acting on the rear locating band. It consists of a lever mounted on a pivot which has been press-fitted into the headstock. A cam on the camshaft actuates the fork roll through a spring. This swivels the clamping lever. An eccentric journal on the lever clamps the carrier down on its lower precisely bored locating surfaces.

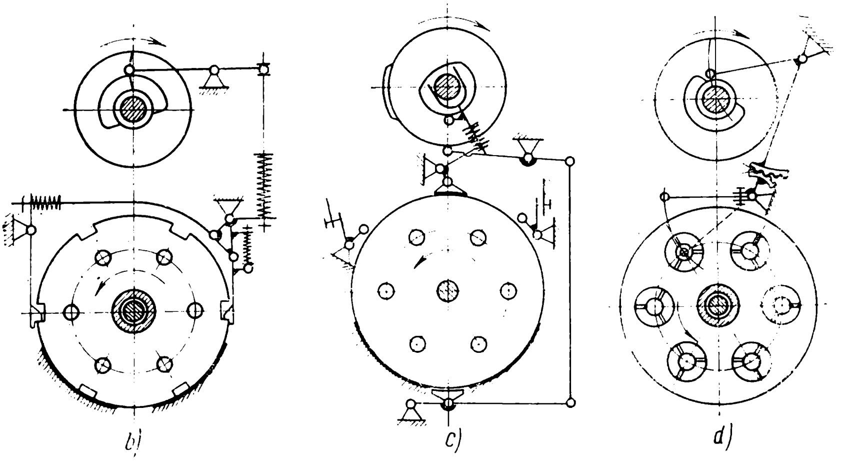


Fig. 181. Diagrams: *b*—carrier locking, *c*—carrier lifting and clamping, *d*—stock stop operation.

Four shoes retain the carrier axially.

All units of the automatic are actuated by cams on the camshaft. Stock is fed by a cam mounted on a cam drum. The cam swivels the lever, through a roll, and a tie-rod, on the other end of the lever, moves the head. This head has a slot into which the collar, on the end of the pusher tube, enters (Fig. 182).

After the bar is chucked by the collet (see Fig. 180), the spindle carrier is indexed and the next feed tube collar enters the head slot. During the working part of the cycle, the head pulls the pusher tube back to its initial position.

The length of stock feed is adjusted by means of the nuts on the tie-rod. The length of stock feed will be 200 *a*, in which *a* is the distance between the pin and nuts.

The design of the end toolslide is clear from Fig. 183 *a*. Rapid approach of this toolslide may be either 120 or 75 mm, while working feed may be adjusted in a range from 20 to 80 mm.

Rapid approach of the end toolslide is effected by the advance of the carriage with the feed lever held stationary. The carriage (Fig. 183 *b*) is traversed by a cam acting through a roll. At the end of its movement, the carriage runs against a stop screw. A gear rotating on

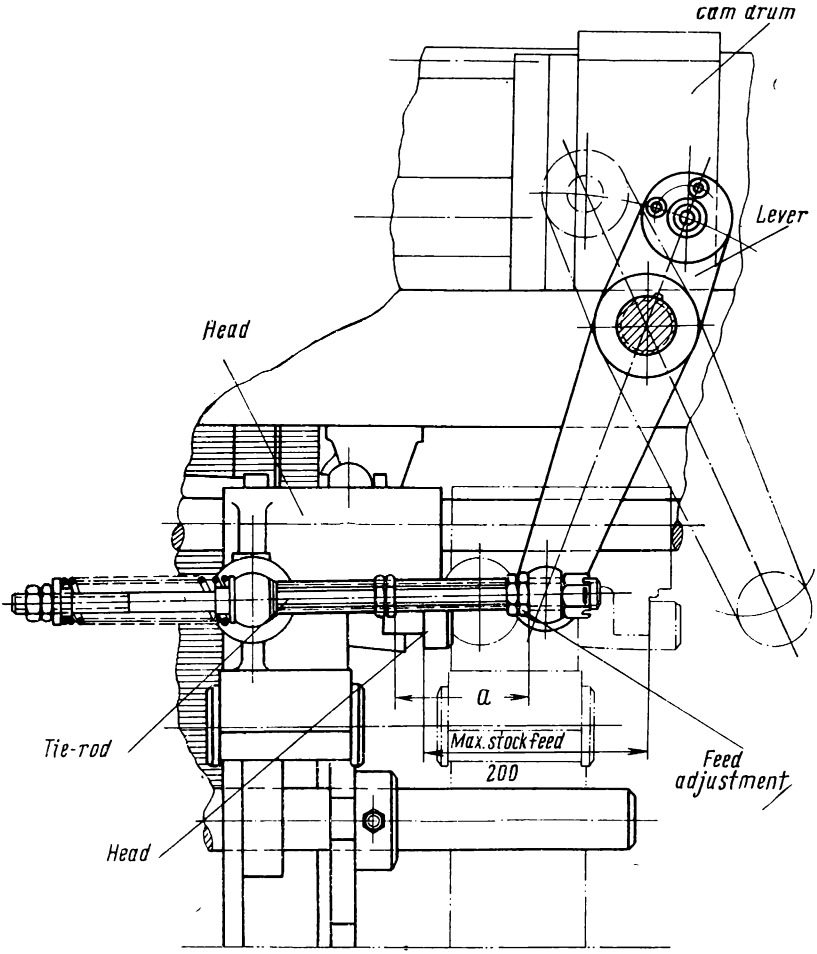


Fig. 182. Stock feeding mechanism of the model 1240-6 automatic.

a pin travels together with the carriage. This gear meshes simultaneously with the rack of the tie-rod and the rack of the end toolslide. Since the rack, linked through a tie-rod to the feed lever is stationary, the end toolslide rack and the toolslide itself will travel a distance twice that of the carriage.

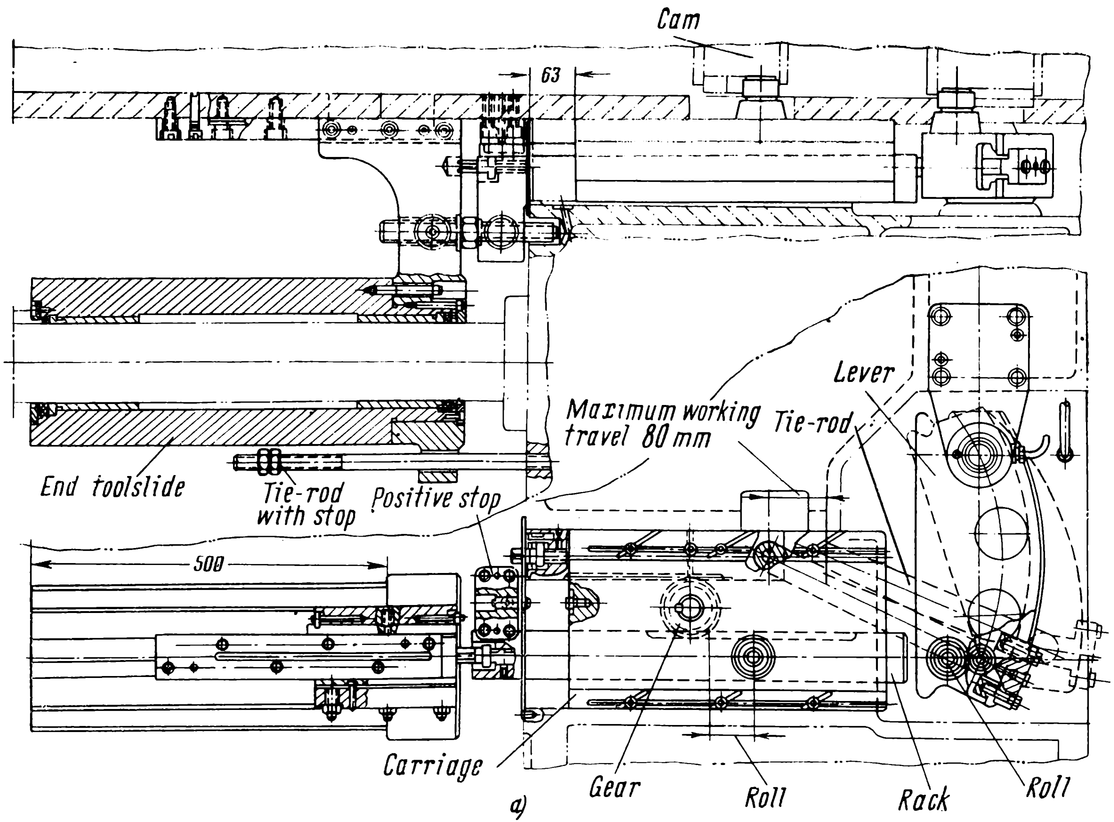


Fig. 183. End toolslide of the model 1240-6 automatic.
a—construction.

At the end of rapid approach, the carriage stops and is held stationary by the stop screw and a cam on the camshaft. Immediately after this, another cam actuates the feed lever which is linked to its rack through the tie-rod. This rack moves the end toolslide rack and the toolslide by means of the gear in the carriage. End toolslide travel depends on the position of the tie-rod attached to the feed lever. This length of working feed is indicated on a scale of the lever. Rapid withdrawal is engaged at the end of working feed. In this case, both the carriage and lever return to their initial positions at the same time.

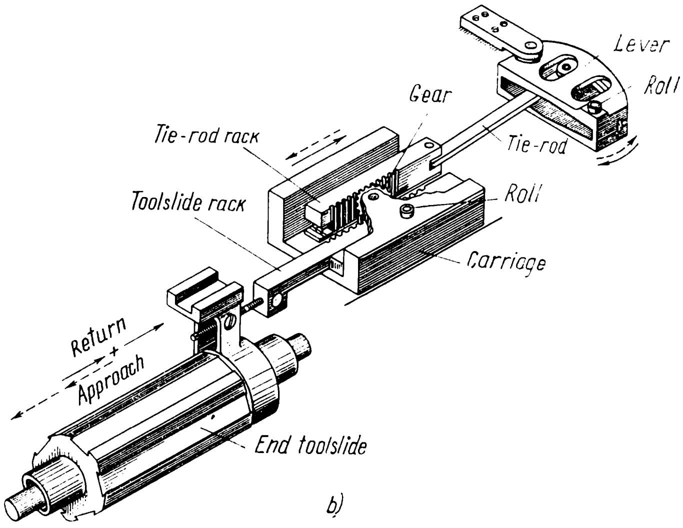


Fig. 183b. Toolslide feed drive.

Holders for the independent-feed tool spindles are used when the feed of any cutting tool must differ from that of the end toolslide *2* travelling on the stem *1* (Fig. 183 *c*).

Holder *3* with a tool spindle has movement controlled by a lever system from constant work and return cams fastened on a drum (see Fig. 179). The roll of sector *4* (Fig. 183 *c*) is in constant contact with the profile of the work cam. The sector swivels on a stationary pin and swings lever *6* through adjustable tie-rod *5*. Lever *6* swivels on a pivot which is linked through adjustable tie-rod *7* with the gearbox *3*. The roll of the moving bar constantly contacts its work cam on the camshaft drum.

The side toolslides (Fig. 184) accommodate interchangeable toolholders which are inserted in the slot of the toolslide. The toolholder is clamped underneath by a taper gib and at the side by a strap clamp with nuts. The toolholder is adjusted longitudinally in the toolslide by means of a taper gib and crosswise by a stop with a micrometric

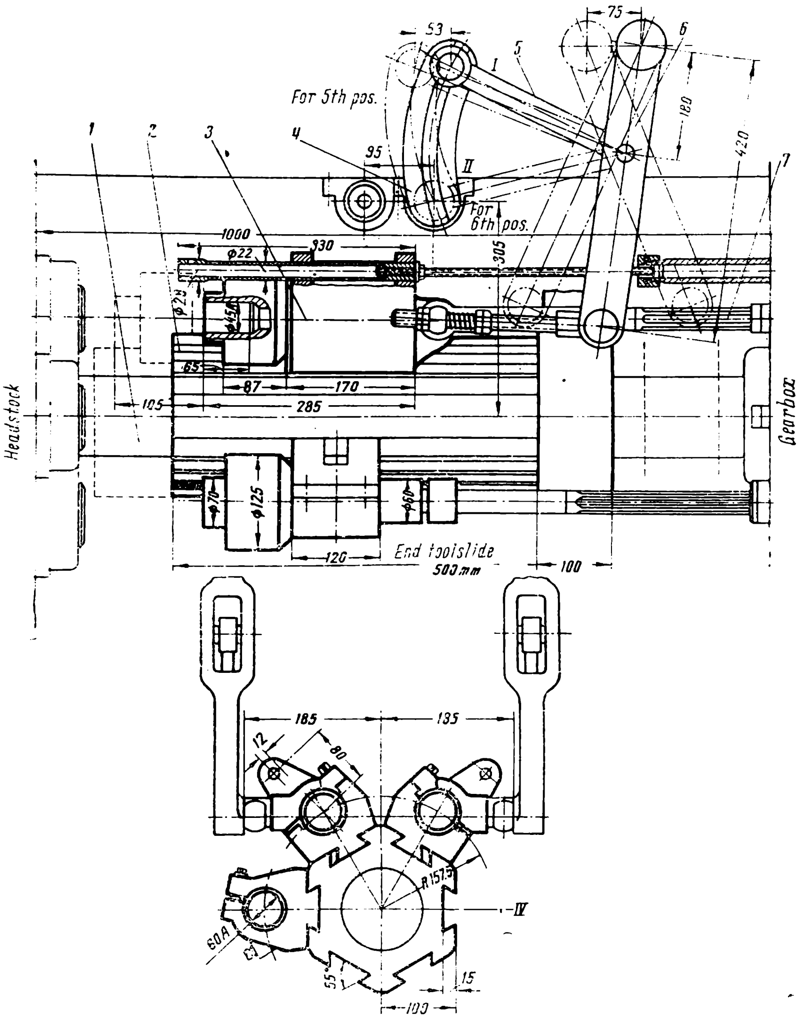


Fig. 183c. Arrangement and drive of the tool spindles.

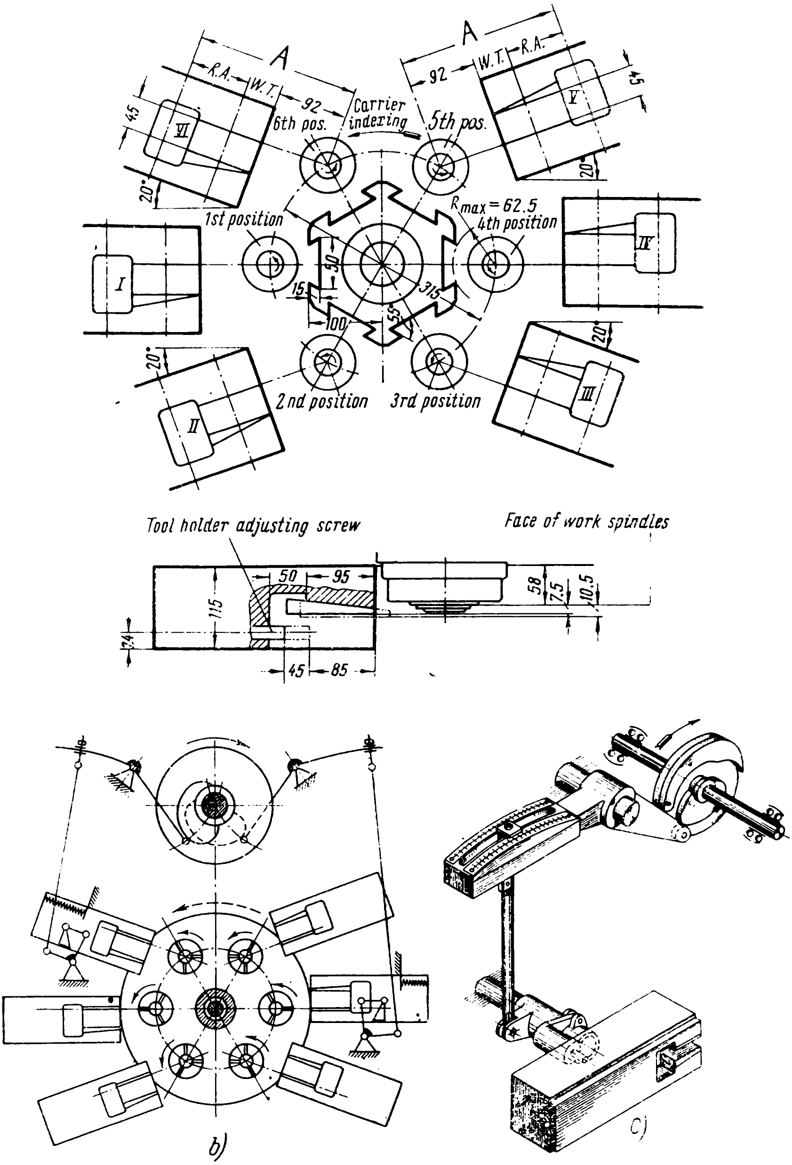


Fig. 184. Side toolslides of the model 1240-6 automatic.
a—arrangement, *b* and *c*—toolslide feed drive.

screw. Both taper gibs and the stop are adjusted from the front end of the toolslide.

Toolslide movement in a range from 0 to 22 mm is accomplished by a lever system actuated by a plate cam (see Fig. 179).

The adjustable levers for side toolslide travel, enclosed by a hinged guard, enable the required working travel to be set up. Travel is set up by means of an adjustable tie-rod secured to the feed lever. Two scales indicate the set-up travel of each slide.

Brackets with six adjustment screws of the positive stops are mounted on the end face of all side toolslides (except for the cut-off toolslide in the 6th position). Each screw limits the travel of the slide when the spindle carrier is in one of its six positions.

In thread cutting, the thread is started by a rapid approach cam on forward travel of the toolholder on the end toolslide.

The cutting tools are cooled by oil delivered from the reservoir in the base by a gear pump. The pump is located inside the base and is driven by roller chain from the gearbox drive shaft.

Lubricant feed is effected by a vane pump mounted directly above the lubricant reservoir. This pump is driven from the same shaft as the coolant oil pump.

A pressure relay, provided in the machine, automatically switches off the main drive motor if the lubricating pump is not delivering oil.

Setting up. A multiple-spindle automatic should be set up to manufacture a certain workpiece after designing the tooling layout and planning the operation sheet in accordance with the rules for planning a manufacturing process of such machines, given in § 62.

The tooling layout for a pipe connection is illustrated in Fig. 171 while Table 27 is the operation sheet for this workpiece as made from hexagon bar stock of steel 35 on the six-spindle automatic bar machine, model 1240-6.

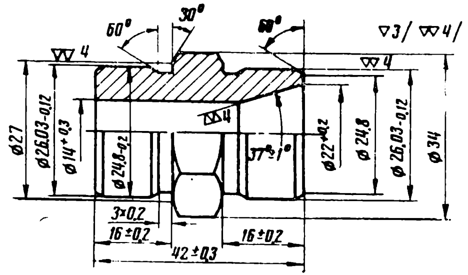
As the sketch indicates, the external diameters and the tapered hole are to have a surface finish of ∇ 4. A finish of ∇ 3 is specified for the remaining surfaces.

The pipe connection must be completely machined and cut off in six positions. The end of the bar is spot drilled (in the 1st position) before drilling; the front end of the bar is also faced in this position. Due to the large depth of the hole, it is drilled in two positions (2nd and 3rd) so that neither limits the rate of production. Drilling in the 2nd position may be combined with turning up to the hexagon. Drilling in the 3rd position may be combined with turning behind the hexagon from a side toolslide. In the 4th position a roughing taper reamer roughs the taper from the end toolslide and a wide form tool in the side toolslide finishes the external surfaces. The taper is finish reamed in the 5th position and the finished work is cut off in the 6th.

Besides cutting off, the stock is fed out and chucked in the 6th position.

Table 27

Tooling Layout and Operation Sheet for the 6-Spindle Automatic Bar Machine, Model 1240-6

<table>
<tr><td rowspan="6">

Workpiece</td><td colspan="4">Change gears</td><td colspan="2">Work spindles</td></tr>
<tr><td></td><td></td><td></td><td></td><td rowspan="2">n_s, rpm</td><td rowspan="2">316</td></tr>
<tr><td>A</td><td>35</td><td>B</td><td>39</td></tr>
<tr><td colspan="6">Camshaft</td></tr>
<tr><td colspan="4">Change gears</td><td>Gearing ratio</td><td>n_{cs}, rpm</td></tr>
<tr><td>C</td><td>33</td><td>D</td><td>49</td><td>0.0017</td><td>1.74</td></tr>
</table>

Part name	Material	Stock	
Pipe connection	Steel 35	30 mm hexagonal bar	

<table>
<tr><th>Pos</th><th>Travel</th><th colspan="2">Operation element</th><th>Machined length L, mm</th><th>Actual travel l, mm</th><th>Cam rise</th><th>Feed s, mm/rev</th><th>Cutting speed v, m/min</th></tr>
<tr><td>1st</td><td>Longitud.
Cross</td><td colspan="2">Spot drill diam 21 . . . .
Face end . . . .</td><td>10
4</td><td>26
5.5</td><td>$P_n - 10$</td><td>0.120
0.026</td><td>20.8
26.8</td></tr>
<tr><td>2nd</td><td>Longitud.
Cross</td><td colspan="2">Drill diam 14, turn diam 26.5</td><td>22</td><td>26</td><td></td><td>0.12</td><td>33.7</td></tr>
<tr><td>3rd</td><td>Longitud.
Cross</td><td colspan="2">Drill diam 14 . . . .
Form to diam 26.5 . . . .</td><td>20
4</td><td>26
5.5</td><td>$P_n - 10$</td><td>0.12
0.26</td><td>13.9
33.7</td></tr>
<tr><td>4th</td><td>Longitud.
Cross</td><td colspan="2">Rough ream taper 37° . . . .
Form full profile . . . .</td><td>10
1</td><td>26
2.7</td><td>$P_n - 5$</td><td>0.12
0.0129</td><td>21.8
33.7</td></tr>
<tr><td>5th</td><td>Longitud.
Cross</td><td colspan="2">Finish ream taper 37° . . . .</td><td>0.5</td><td>4</td><td></td><td>0.018</td><td>21.8</td></tr>
<tr><td>6th</td><td>Longitud.
Cross</td><td colspan="2">Cut off from diam 25 . . . . .</td><td>5.5</td><td>8</td><td>$P_n - 10$</td><td>0.0378</td><td>24.8</td></tr>
<tr><td colspan="2">Working feed angle</td><td>140°</td><td>Machining time, sec</td><td>43.5</td><td colspan="4">Rate of production</td></tr>
<tr><td colspan="2">Idle motion angle</td><td>220°</td><td>Idle time, sec</td><td>2.1</td><td colspan="2" rowspan="2">Gross Q_g'</td><td rowspan="2">79</td><td rowspan="2">pcs/hr</td></tr>
<tr><td colspan="2"></td><td></td><td>Total machine time, sec</td><td>45.6</td></tr>
<tr><td colspan="2"></td><td></td><td>Cycle time, sec</td><td>45.6</td><td colspan="2">Actual Q_a' (20% loss)</td><td>63</td><td>pcs/hr</td></tr>
</table>

The next step is to make all the calculations which are set down in the operation sheet. The most difficult operation element is forming and a cutting speed of 35 m per min is selected for this work. Then the work spindle speed will be: $n_s = \frac{35 \times 1,000}{\pi d} \approx 328$ rpm. The next lower speed available on this automatic and listed in the service manual will be $n_s = 316$ rpm which corresponds to a cutting speed $v = 33.7$ m per min.

This spindle speed may be obtained by installing change gears $A = 35$ and $B = 39$ teeth.

Then, from the length to be machined, the actual travel of the toolslides is determined, as well as the rate of feed.

The number of spindle revolutions is determined for the longest operation element:

$$n_o = \frac{l}{s} = \frac{26}{0.12} \approx 220 \text{ revolutions.}$$

This operation element must be performed in 135.5° of camshaft rotation, i. e., in $60 \times \frac{220}{316}$ sec. Besides this, 4.5° of camshaft rotation is required to engage the high-speed clutch.

Therefore, slow or working speed rotation of the cams will take up $135.5^\circ + 4.5^\circ = 140^\circ$ of camshaft rotation and the time required for the longest operation element will increase in the proportion $\frac{140^\circ}{135.5^\circ}$ or

$$t_w = 60 \frac{220}{316} \times \frac{140}{135.5} \approx 43 \text{ sec.}$$

A machining time of 43.5 sec (the nearest larger value) is selected from the service manual and the corresponding change gears, $C = 33$ and $D = 49$ teeth, are installed.

The cycle time will therefore be:

$$T_c = t_w + t_i = 43.5 + 2.1 = 45.6 \text{ sec.}$$

The gross production will be:

$$Q_g' = \frac{60 \times 60}{T_c} = \frac{3,600}{45.6} \approx 79 \text{ pcs per hr}$$

and the actual production (minus losses) will be:

$$Q_a' = Q_g' \eta = 79 \times 0.8 = 63 \text{ pcs per hr.}$$

The actual setting up consists in installing the change gears A, B, C, and D to obtain the required spindle and camshaft speeds.

The change gears should slip on their shafts with little effort. *Never use steel hammers to drive on the change gears.*

Cams are installed as shown in Figs. 178 and 179. Then the lever systems are adjusted to the required toolslide travel values.

Before changing the cams, in changing over for a new setup, it is necessary to check whether any cams of the preceding setup may be used; if so, setting-up time may be correspondingly reduced.

The positions of the cams for engaging high speed camshaft rotation and for applying the brake at the end of high-speed rotation are checked next (a constant-action brake is used in certain models and it requires no engagement). The brake must be in proper adjustment. This may be checked by rotating the camshaft manually.

Collets and pushers and their tubes are changed if, in the new setup, the form or size of the bar stock is to be changed. For this purpose, it will be necessary to remove the nuts at the ends of the spindles, to remove the tubes from the spindles (see Fig. 180), and to carefully unscrew the collets and pushers from the tubes with a special wrench. *Never unscrew collets or pushers by inserting wire or a screw driver into their slits.* After screwing on the new collets, the tubes are inserted into the spindles and nuts are put on the rear ends. Then the stock feed tubes are installed.

The amount of stock feed is adjusted by turning the nuts on the threaded tie-rod and by changing the arm length of the feeding lever. The nuts change that part of tie-rod movement that does not cause feeding fork movement. Changing the lever arm length will change the tie-rod movement.

Bar stock feed is effected by constant cams on the camshaft drum which need not be changed or adjusted for a new setup.

The stock chucking mechanism is adjusted by means of the hand chucking lever (see Fig. 175). A projection of this lever enters a slot in the chucking fork. Hand chucking checks whether the collet is overstrained in chucking.

The operator should always be careful not to injure his hands by getting them between the hand chucking lever and the headstock.

The stock stop is set to the centre of the bar and to the proper length of stock feed. This is done by securing the bracket in the corresponding hole. Fine adjustment is made with the screw of the stop which is afterwards locked with a nut. If the front end of the bar is to be faced, the distance from the stop to the right-hand side of the cutting off tool should be from 0.5 to 1 mm longer than the workpiece length.

The cutting tools are installed and adjusted in the following manner:

The tools are clamped in their holders and installed in the side toolslides and on the end toolslide. The tools are set to the size of the finished workpiece with the slides in positions where their cam rolls are on the high points of the cams. The more accurate dimensions of the work are obtained by positive stops. These stops are also adjusted with the rolls on the high points of their cams. The proper tension, after the stop screw contacts the stop button, is obtained by giving the stop screw an extra half or whole turn. The stop screw is locked after adjustments are made.

Straight turning tools on the end toolslide are set by screws.

The travel of independent feed tool spindles is varied by changing the arm lengths of their driving levers. These spindles may also operate to positive stops which are installed on the slide blocks.

The setting of the cutting tools is checked by making a test workpiece.

Threading is usually performed in the 4th and 5th positions. If solid taps or dies are employed, change gears must be installed both for advancing and backing out the threading spindle. After this, the tool is set in reference to the work in the ordinary manner.

If the thread is to be cut by a self-opening die head, the latter must be adjusted to size and then installed on the automatic. The feed cam is to be replaced by a threading cam. A special stop is provided to open the die head at the proper time. The tensioning spring of the threading attachment must be adjusted so that it exerts a sufficient force to start the thread when the tool reaches the work.

Cutting tools, positive stops, and stock feeding and chucking mechanisms are adjusted with the automatic switched over to setting-up operation, i. e., using the inching push button and the setting-up drive motor (in earlier models, manual rotation of the camshaft was required). After adjusting all the units and setting all the tools, work spindle rotation is switched on and the cycle is run through manually (or by inching). Checking the dimensions of the workpiece at each position will reveal the tools that require further adjustment before starting regular automatic operation.

The operator of earlier models of multiple-spindle automatics must always remember to remove the crankshaft rotation handwheel and all other levers used only for setting up before engaging the automatic cycle.

§ 103. FOUR-SPINDLE AUTOMATIC BAR MACHINE, MODEL 1240-4

Four-spindle automatics differ from six-spindle models in the same size range only in that they have four work spindles and are designed for machining simpler work than the six-spindle models.

This chief difference between models 1240-4 and 1240-6 requires certain changes in laying out work on these automatics. As in the six-spindle automatic, stock feeding and chucking take place in one position which may also be used for cutting off the preceding finished workpiece. Therefore, only three positions remain for all of the external and internal machining (instead of five in six-spindle automatics) and the operation elements must be divided between these three positions so that the machining time is as nearly equal as possible in each position.

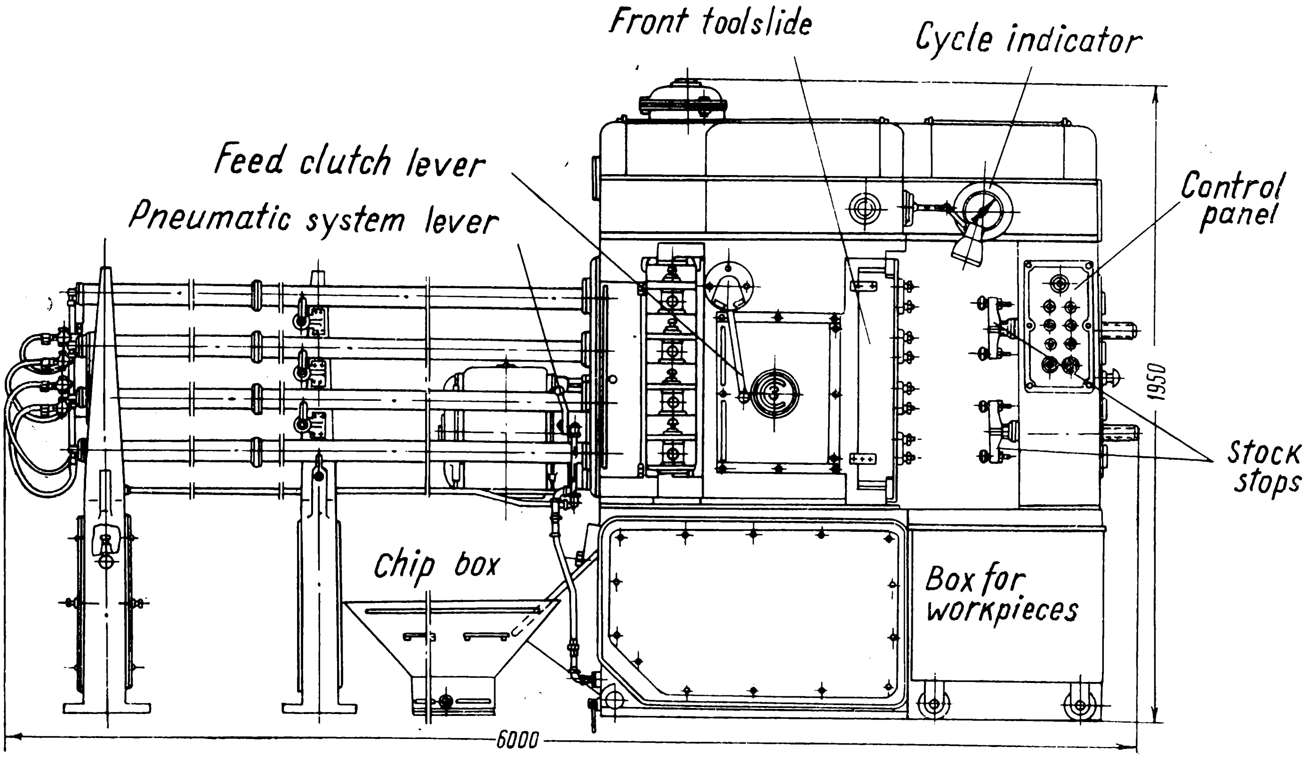


Fig. 185. Four-spindle straight automatic bar machine, model 1240-0.

On four-spindle automatics, external surfaces are usually turned by one or two form tools, another position is used for cutting various grooves and the forth position, as mentioned above, is for cutting off.

Holes are drilled with one or two drills and then they are reamed or tapped.

§ 104. FOUR-SPINDLE STRAIGHT AUTOMATIC BAR MACHINE, MODEL 1240-0

These automatics (Fig. 185) are designed for machining comparatively simple work of bar stock up to 40 mm in diameter.

The gear trains of the model 1240-0 automatic (Fig. 186) differ from those of models 1240-6 and 1240-4. Model 1240-0 has a headstock but no gearbox and is simpler in operation and maintenance. The top brace houses a camshaft which controls all movements of the units.

The work spindles are arranged in a vertical line, one above the other, while the main drive shaft is at one side. Each pair of spin-

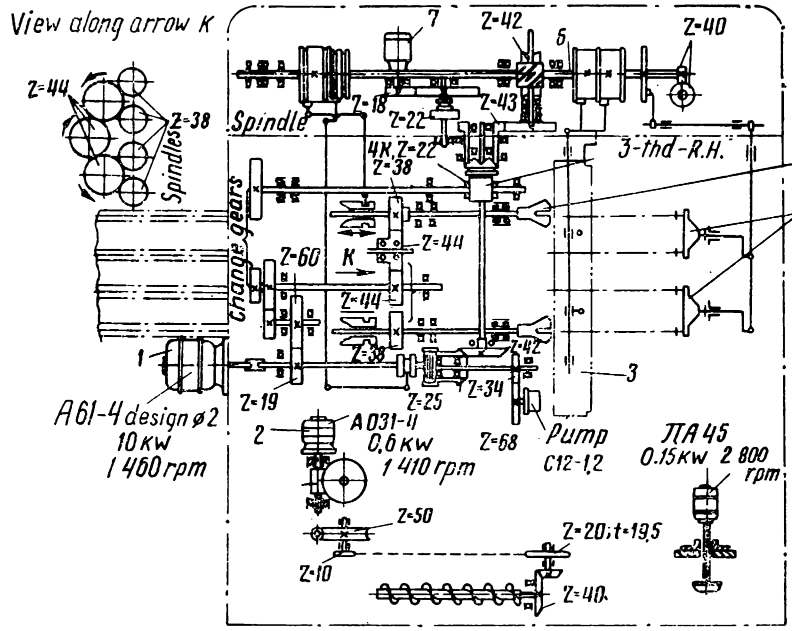


Fig. 186. Gearing diagram of the model 1240-0 automatic.
1—main drive motor, 2—chip conveyer motor, 3—toolslides, 4—stock stops, 5—spindles, 6—camshaft, 7—setting-up drive motor.

dles is driven by a single gear so that all spindles rotate in the same direction.

The design of the spindles and their supports is the same as in model 1240-6. Stock is fed by an air-operated device to the stock stops. The bar is chucked by collet and tube movement to the right. The same type of work may be machined as on single-spindle automatic cutting-off machines (see Figs. 96 and 97).

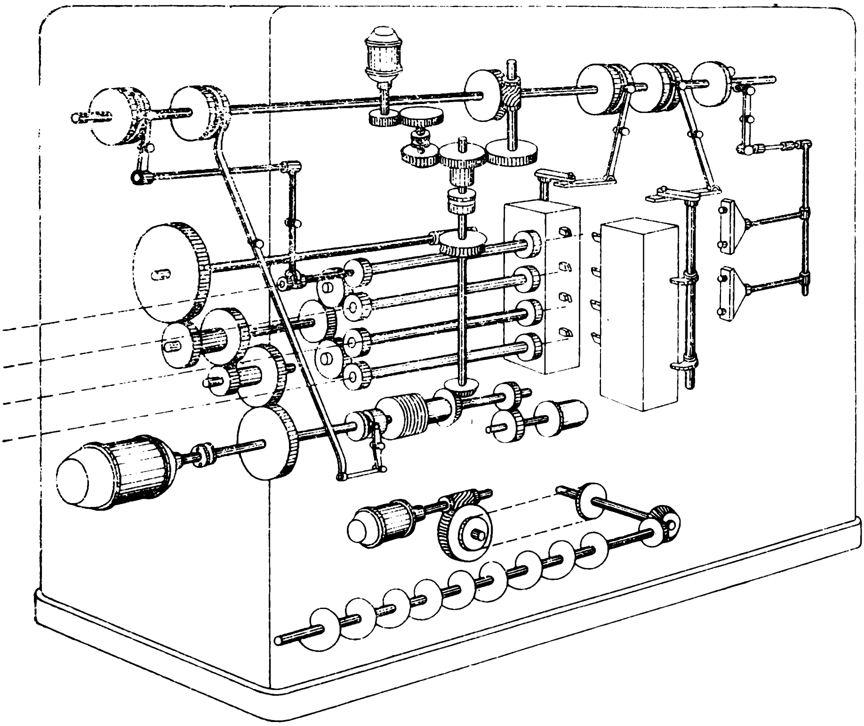


Fig. 187. Isometric diagram of the model 1240-0 automatic.

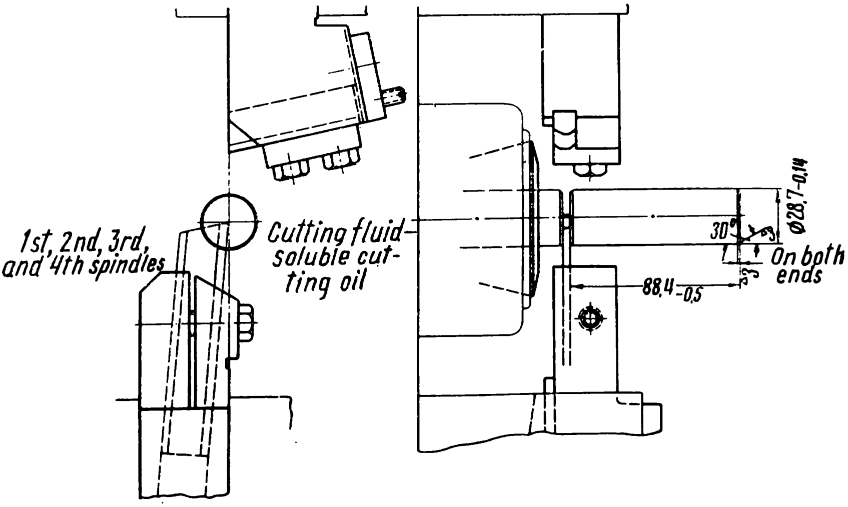
Two cross-feeding side toolslides are provided, one on each side of the line of work spindles. Each toolslide serves all four spindles. One toolslide performs forming operations while the other cuts off the finished workpieces. An isometric diagram of this automatic is shown in Fig. 187. Four identical workpieces are machined at the same time and therefore four pieces will be made in each cycle.

The cycle indicator enables the completion of each element of the cycle to be checked.

A tooling layout and operation sheet for the four-spindle straight automatic bar machine, model 1240-0, is given in Table 28.

Table 28

Tooling Layout and Operation Sheet for the 4-Spindle Straight Automatic Bar Machine, Model 1240-0



1st, 2nd, 3rd, and 4th spindles
Cutting fluid-soluble cutting oil
30°
Ø28.7-0.14
On both ends
88.4-0.5

Material	Steel 15X
Cross-section and size	Round bar 28.7-0.14 mm
Work spindle speed n_s, rpm	347
Cutting speed v, m per min	31.2
Speed change gears Z'_{cg}	32:49
Rear toolslide travel L, mm	2
Rear toolslide feed s, mm per rev	0.017
Front toolslide travel L, mm	16
Front toolslide feed s, mm per rev	0.061
Feed change gears Z''_{cg}	28:55
Cycle time T_c, sec	49
Time per piece, sec	12.25

§ 105. SIX-SPINDLE SEMI-AUTOMATIC CHUCKING MACHINE, MODEL 1240-6II

The model 1240-6II semi-automatic is designed for machining separate blanks up to 80 mm in diameter or even up to 120 mm for finishing operations.

The only alterations made in this model, in comparison with the above-described bar-type machine, model 1240-6, are those necessary for accommodating larger workpieces held in a jaw chuck. The main drive and camshaft drive gear trains were subject to no change whatsoever.

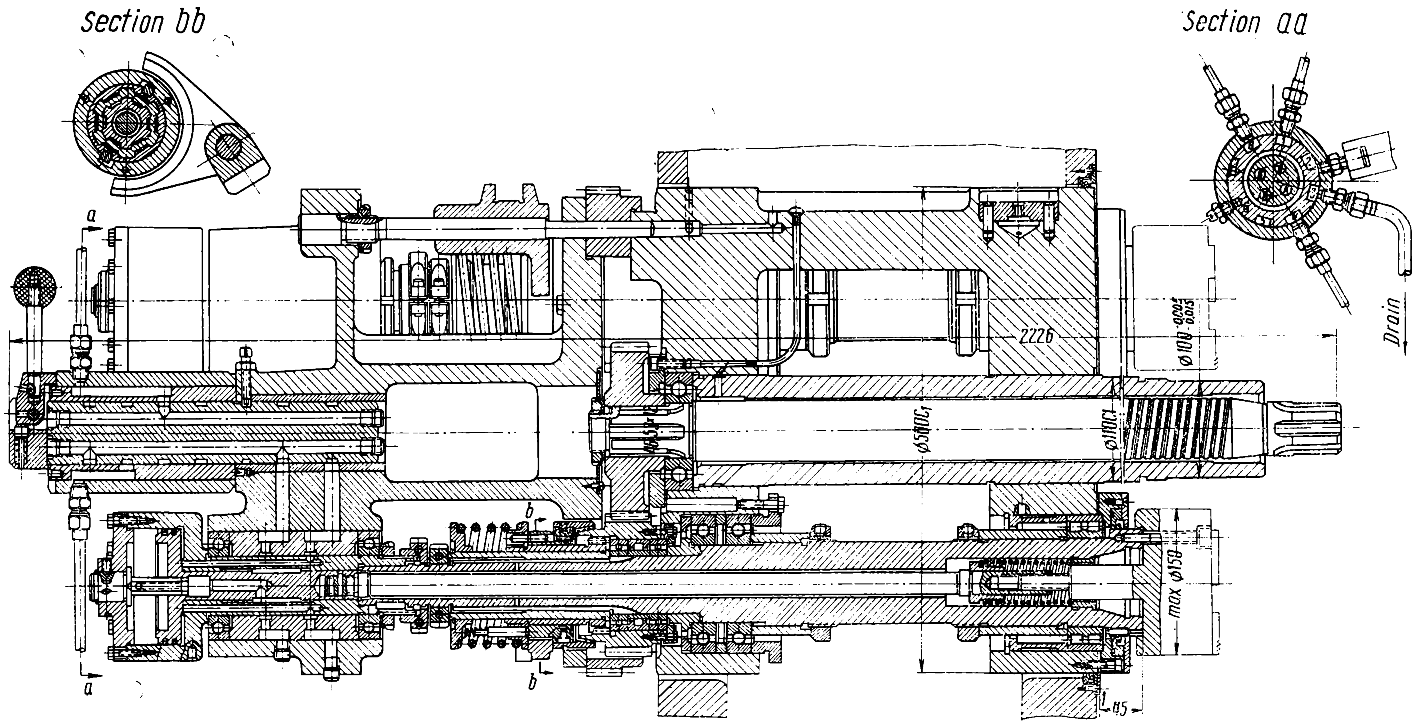


Fig. 188. Section through a spindle of the model 1240-6П semi-automatic.

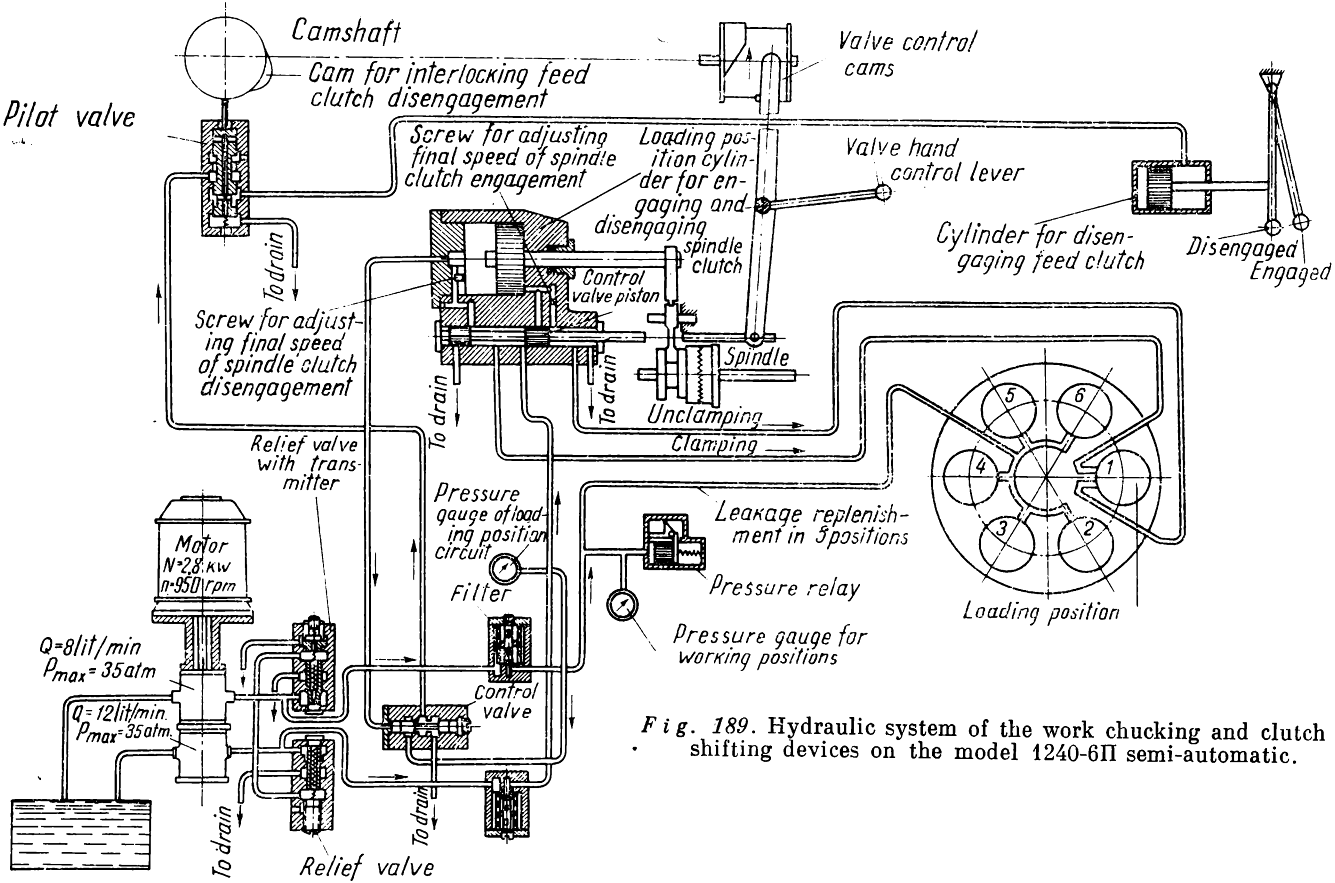

Camshaft
Cam for interlocking feed clutch disengagement
Pilot valve
Valve control cams
Screw for adjusting final speed of spindle clutch engagement
Loading position cylinder for engaging and disengaging spindle clutch
Valve hand control lever
Cylinder for disengaging feed clutch
Disengaged
Engaged
To drain
Control valve piston
Screw for adjusting final speed of spindle clutch disengagement
Spindle
To drain
To drain
Unclamping
Clamping
5
6
4
1
3
2
Relief valve with transmitter
Pressure gauge of loading position circuit
Leakage replenishment in 5 positions
Motor
N=2.8 kw
n=950 rpm
Filter
Pressure relay
Loading position
Q=8 lit/min
P_{max}=35 atm
Pressure gauge for working positions
Control valve
Q=12 lit/min.
P_{max}=35 atm.
To drain
To drain
Relief valve

Fig. 189. Hydraulic system of the work chucking and clutch shifting devices on the model 1240-6П semi-automatic.

Since the sixth position serves for loading, rotation of each spindle is automatically disengaged in this position (Fig. 188) by a hydraulically-controlled clutch. The work is loaded and unloaded by hand and clamped by hydraulic action (Fig. 189).

The clutch, which disengages and re-engages each spindle in the loading position, operates from a cam on the camshaft. Through a lever system, this cam shifts a control valve piston to allow oil to enter either the right or left end of a hydraulic cylinder. The piston rod of this cylinder engages or disengages the spindle drive clutch. The clutch may also be manually operated from a lever.

The hydraulic system is designed so that the spindle drive clutch may be engaged only after the new blank has been clamped in the loading position. For this reason, oil delivery to the chucking cylinder in the loading position is separated from oil delivery in the other positions and is interlocked with chuck operation. In the

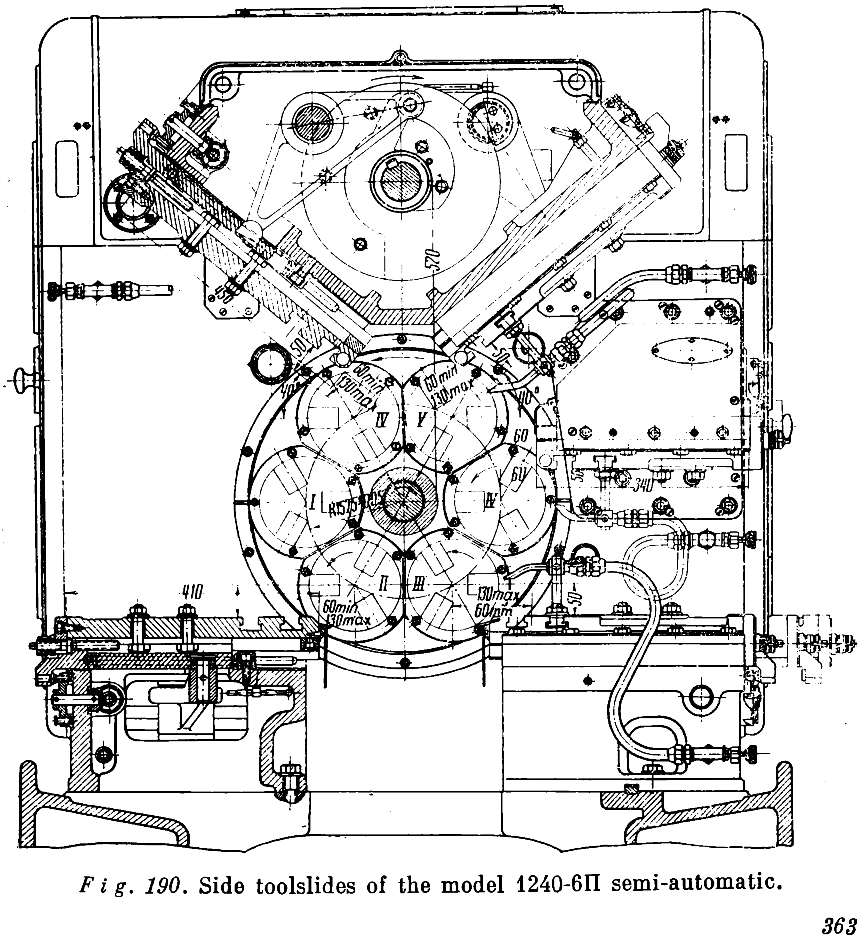


Fig. 190. Side toolslides of the model 1240-6П semi-automatic.

other positions, only replenishment of the oil, lost in leakages in the chucking cylinders, takes place.

Five independent side toolslides of the platen type (Figs. 190 and 191) are provided. Kinematic linkages for driving the side toolslides are as short as possible. For this purpose, the camshaft has vertical branches or sections mounting plate cams. Except for these details, the construction and setting up of this semi-automatic lathe are the same as for model 1240-6.

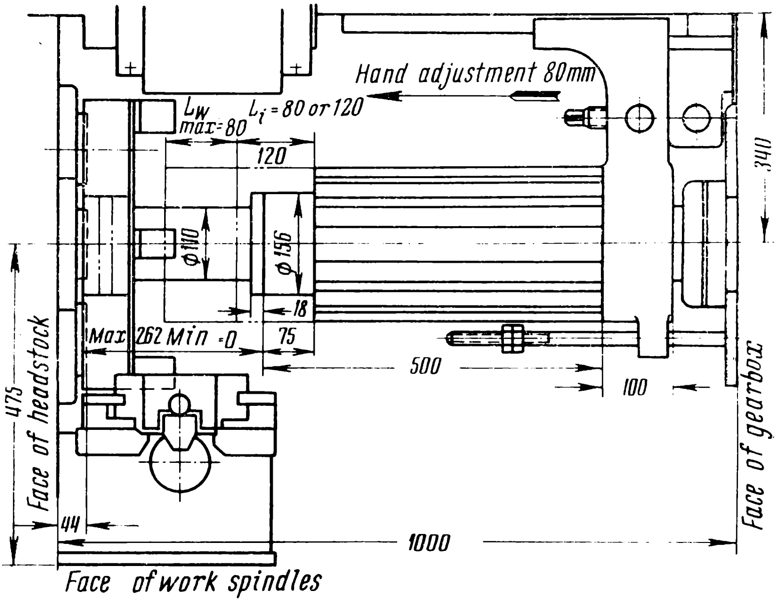


Fig. 191. Tooling chart for the model 1240-6П semi-automatic.

§ 106. NEW LARGE-SIZE MULTIPLE-SPINDLE AUTOMATIC BAR AND CHUCKING MACHINES

The specifications for this line of large-size machines are also listed in Tables 25 and 26. Six-spindle automatic bar machines, model 1265, have a bar (or pipe) capacity of 65 mm while the model 1265П semi-automatic is designed for machining separate blanks up to 160 mm in diameter. These machines, similar to those described earlier, are of rigid frame type design with an overhead location of the main camshaft. Their gear trains and general arrangement (Figs. 192 and 193) are also very similar to those described above for models 1240-6 and 1240-6П (see Fig. 176) but have certain advantageous features. Among these is a sliding double cluster gear in their main drive which enables the machines to be quickly

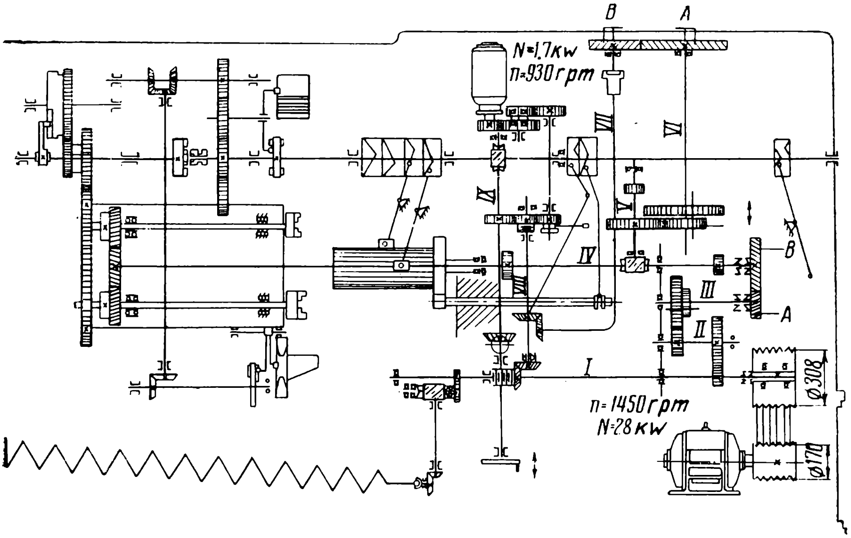


Fig. 192. Line gearing diagram of the model 1265П semi-automatic.

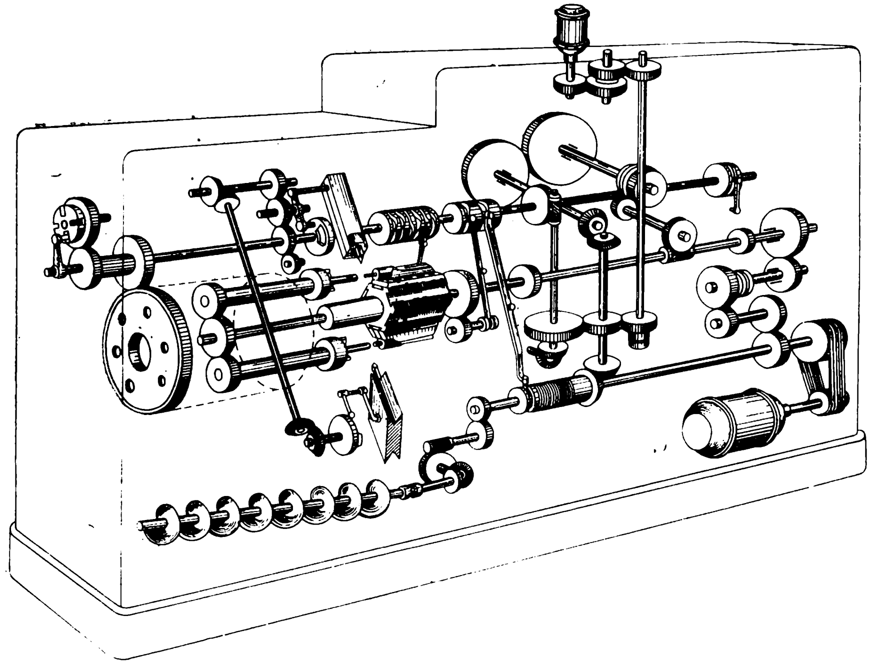


Fig. 193. Isometric gearing diagram of the model 1265П semi-automatic.

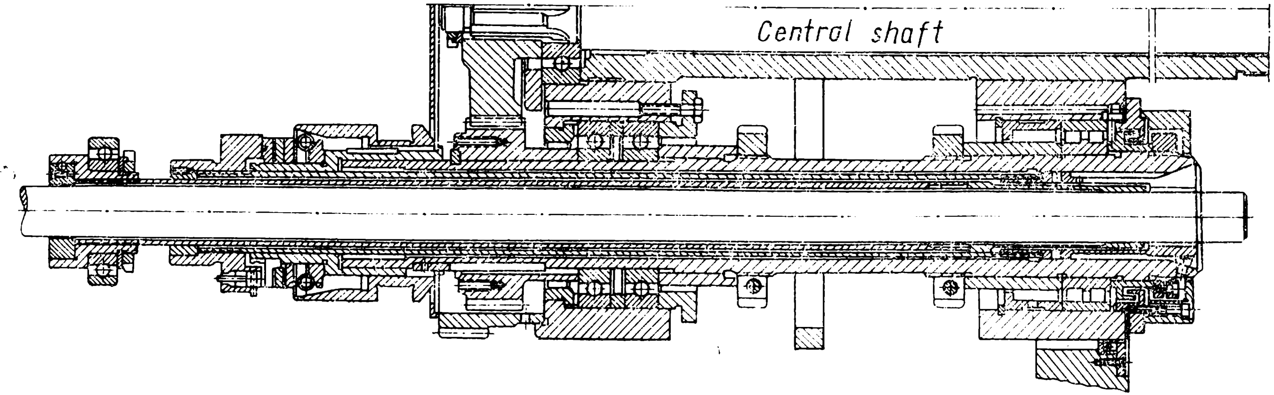


Fig. 194. Section through a spindle of the model 1265 automatic.

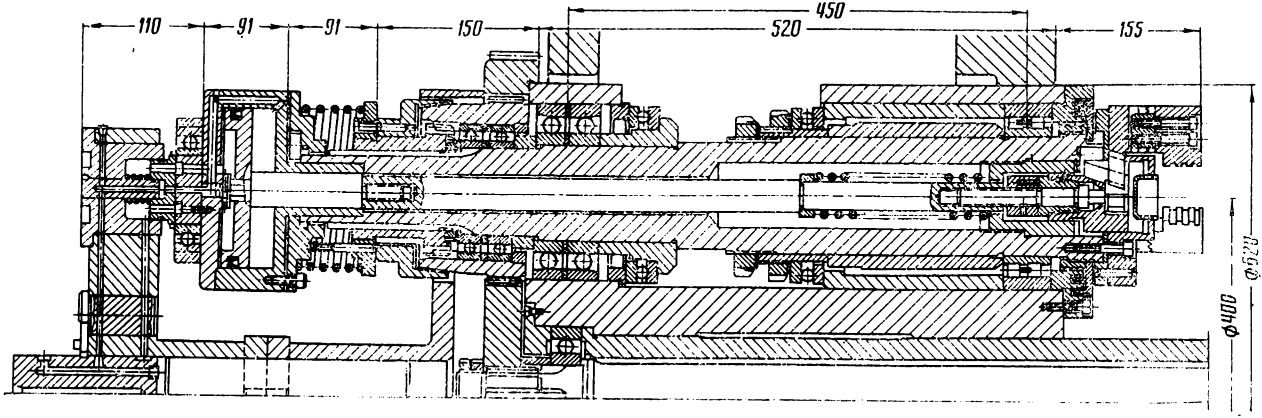


Fig. 195. Section through a spindle of the model 1265П semi-automatic.

changed over for machining work with cemented carbide-tipped tools or for machining work of another material (from steel to brass, for example). Other features are camshaft sections for shortening the linkage between the cam mechanism and the side toolslide drive and the provision of a separate motor for inching rotation of the camshaft to facilitate setting-up operation with the idle motion drive switched off.

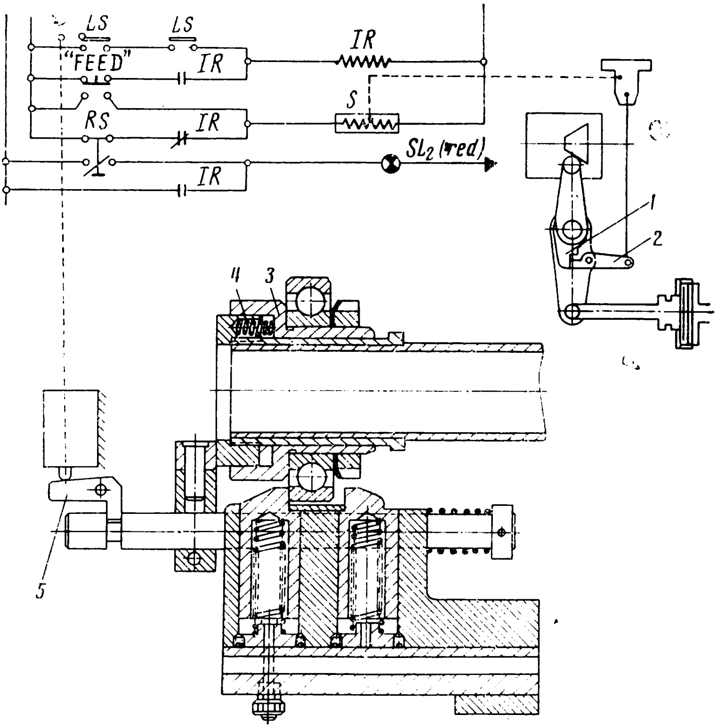


Fig. 196. Device for stopping operation when a bar of stock is completely used up on the model 1265 automatic.

Since accuracy in operation depends to a considerable extent on the design of the spindles and carrier, these units are of ample size to ensure a high rigidity. The double-locking system is applied for the carrier and the spindles run in double-row cylindrical roller bearings (Figs. 194 and 195). Axial loads are carried by high-precision ball thrust bearings. The feeding tubes have independent flexible bearings with wound rollers.

These automatics are equipped with a device for automatically stopping operation when a bar of stock is completely used up in one of the spindles (Fig. 196). While the bar in the spindle is still of sufficient length, springs *4* in the collar of the feeding tube are compressed by the drag of the pusher when it is pulled back over the bar. The compressed springs allow their ring to enter the sleeve *3*. When the bar is used up, the pusher slides off the end of the bar when it is pulled back. This releases springs *4* which push the ring to the left to shift the tie-rod and to trip the limit switch through lever *5*. The limit switch closes the intermediate relay *IR*, the solenoid is de-energised and the signal lamp lights up. At this, lever *2* swivels on its pivot to lock lever *1*. At the end of the cycle, a cam on the camshaft turns lever *1* to disengage the feed clutch and so to stop the camshaft.

Complete automaticity may be achieved in loading and chucking separate blanks by employing a magazine-feed device which is usually installed on the front intermediate side toolslide for the 6th position (Fig. 197).

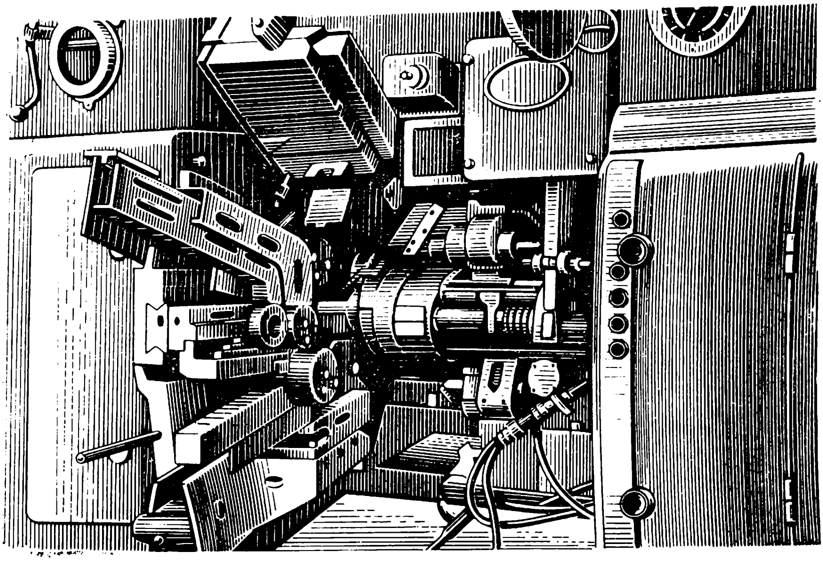


Fig. 197. Six-spindle magazine-feed automatic chucking machine.

In the model 1265П semi-automatic, separate blanks are clamped in hydraulic chucks with a rear oil distributor (Fig. 198). This chuck differs very slightly from the one used on model 1240-6П and described above (see Fig. 188).

All positions are served by independently operated side toolslides. The lower side toolslides travel on ways attached to the vertical surface of the spindle carrier housing (headstock). The top toolslides are mounted on the top brace which is of ample width to accommodate various special attachments. The side toolslides are arranged so that they do not encumber the tooling zone or hinder chip disposal to the conveyer in the base. The intermediate side toolslides are the flat type since they are designed for cutting off, grooving, and other comparatively light work. In the semi-automatic chucking machines, the intermediate side toolslides are the same type as the lower toolslides.

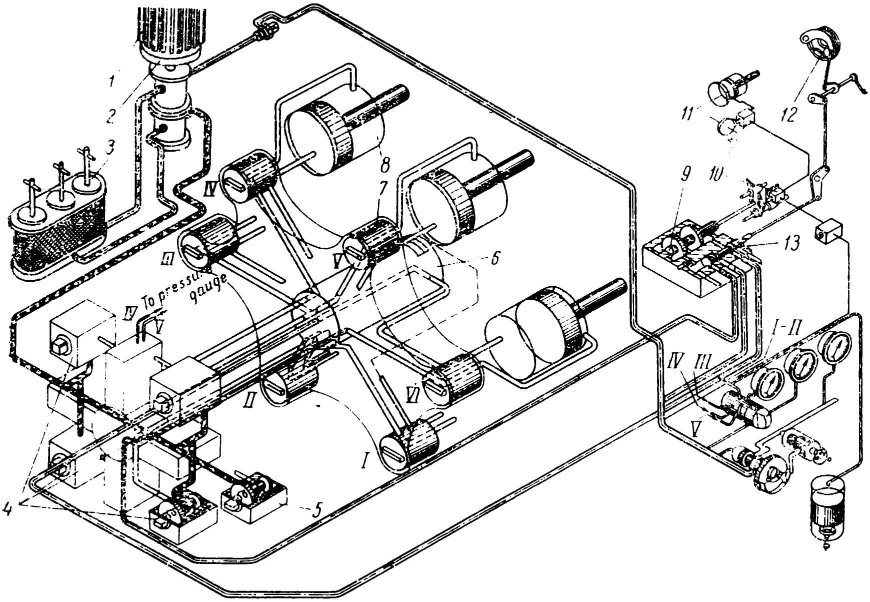


Fig. 198. Hydraulic system diagram for the model 1265П semi-automatic.
1—motor, *2*—pump unit of two pump sections, *3*—screen filters, *4*—reducing valves, *5*—relief valve of working positions, *6*—central valve, *7*—rotary work chucking valve, *8*—chucking cylinder, *9*—control cylinder, *10*—four-way valve, *11*—automatic stop mechanism cylinder, *12*—control cam of hydraulic system, *13*—control valve.

The end toolslide is of ample length and rigidity to ensure minimum wear on the stem. Rotary tool spindles with independent feed may be installed in the 3rd and 6th positions.

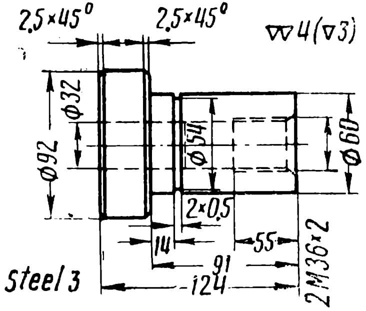
The toolslides are lubricated by a lubricator which delivers metered quantities of oil under pressure.

A set of eight interchangeable cams, enabling any side toolslide travel value, in the capacity of the machine, to be obtained, reduces time required for setting up. The end toolslide is controlled by a constant cam. Its travel is varied by changing the transmission ratio of a lever system.

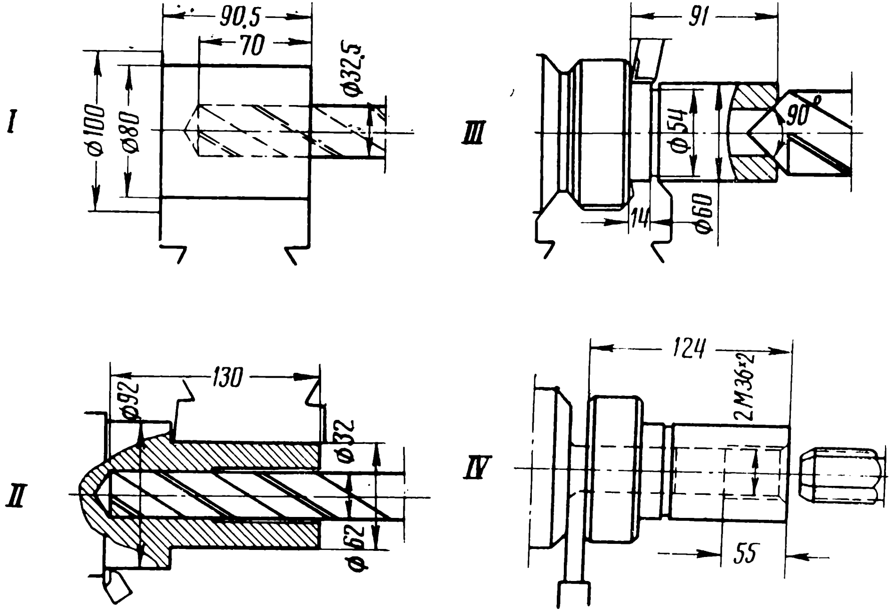
To facilitate setting up, the left-hand section of the camshaft may be disengaged. As a result, the toolslides will go through their cycle of motions without carrier indexing. This means that all the

Table 29

Tooling Layout and Operation Sheet for the 4-Spindle Automatic Bar Machine, Model 1290



Workpiece Sketch



Tooling Layout

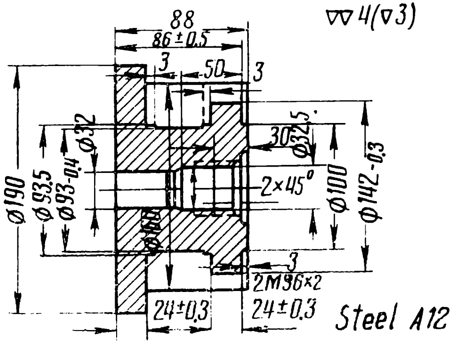
Pos.	Operation element		Working travel, mm	Actual machined length, mm	Depth of cut, mm	Feed, mm/rev	Spindle rev for working travel	Spindle rev for travel plus dwell	Spindle speed, rpm	Cutting speed, m/min
	No.	Description								
1st	1	Form to diam 80 with cross feed . .	26	10		0.05	519	537	133	41.8
	2	Drill diam 32.5	100	80		0.193	519	537	133	13.5
2nd	3	Form to diam 62 with cross feed . .	26	15		0.05	519	537	133	33.5
	4	Drill diam 32	100	70		0.193	519	537	133	13.2
		Turn 92 from end toolslide			4	0.193				41.8
3rd	5	Chamfer in hole	100	5		0.193	519	537	133	17
	6	Turn diam 60	100	91	1	0.193	519	537	133	25.8
	7	Form	26	6.5		0.05	519	537	133	41.8
4th	8	Tap thread	60			2	30	263	65.2	7.3
	9	Cut off	32			0.06	—	537	133	36.5

Machining time $t_w = 4.03$ min
Idle time $t_i = 0.083$ min

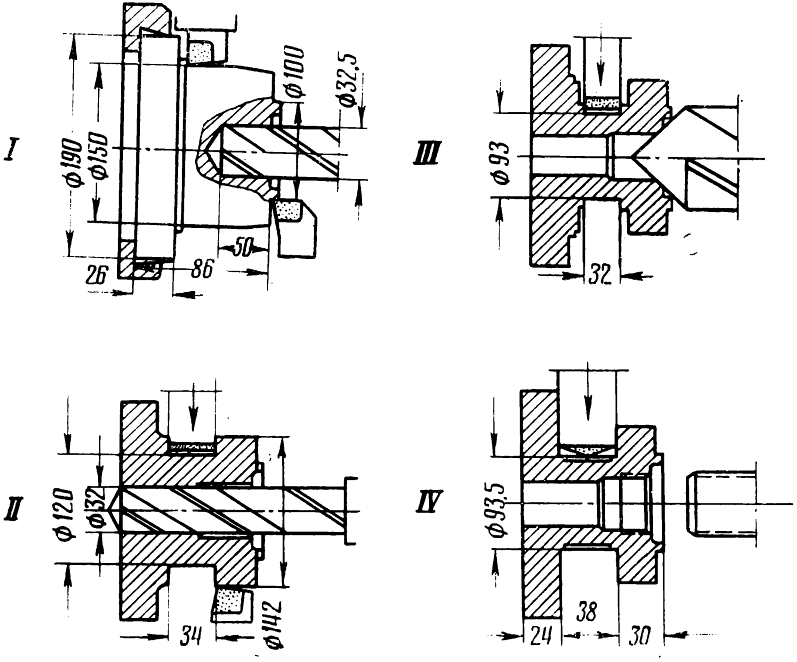
Cycle time $T_c = 4.11$ min
Actual production $Q_a = 14.6$ pcs/hr

Table 30

Tooling Layout and Operation Sheet for the 4-Spindle Semi-Automatic Chucking Machine, Model 1290 II



Workpiece Sketch



Tooling Layout

Pos.	Operation element		Working travel, mm	Depth of cut, mm	Feed, mm/rev	Spindle rev for working travel	Spindle rev for travel plus dwell	Spindle speed, rpm
	No.	Description						
I	1	Drill diam 32.5	60	16.25	0.275	214	218	162
	2	Turn to diam 150	60	5.0	0.275	214	218	162
	3	Face end	28	2.0	0.130	214	218	162
II	4	Drill diam 32	60	16.0	0.275	214	218	162
	5	Turn to diam 142	60	4.0	0.275	214	218	162
	6	Turn to diam 120 with cross feed	18	34.0	0.083	—	218	162
III	7	Turn to diam 93 with cross feed	16	32.0	0.074	—	218	162
	8	Enlarge hole	60	—	0.275	214	218	162
IV	9	Turn to diam 93.5 with cross feed	50	6.0	0.23	—	218	162
	10	Tap thread	30	1.75	2		—	80
	11	Unload finished work and load new blank						

Machining time $t_w = 1.385$ min
Idle time $t_i = 0.08$ min
Cycle time $T_c \approx 1.47$ min

Gross production $Q'_g \approx 40$ pcs/hr
Actual production $Q'_a = 35$ pcs/hr.

cutting tools may be set up and adjusted to a single blank. The two sections of the camshaft may be re-engaged only in a single definite position so that the sequence of movements of the cyclogram is retained.

Chips are disposed of in models 1265 and 1265П with a screw conveyer located in the base.

One safety measure is the provision of limit switches which switch off the main drive motor if the doors, enclosing the various setting up elements, are not closed.

§ 107. HEAVY-DUTY FOUR-SPINDLE AUTOMATIC BAR AND CHUCKING MACHINES

The automatic bar machine, model 1290, is designed with a bar or pipe capacity of 100 mm; the semi-automatic chucking machine, model 1290П, is designed for separate blanks up to 250 mm in diameter.

The gear trains, general arrangement, setting up and operation of the machines in the 1290 range (Fig. 199) differ only slightly from each other and from the above-described models 1265 and 1265П.

Tooling layout and operation sheets for the model 1290 automatic and the model 1290П semi-automatic are given in Tables 29 and 30.

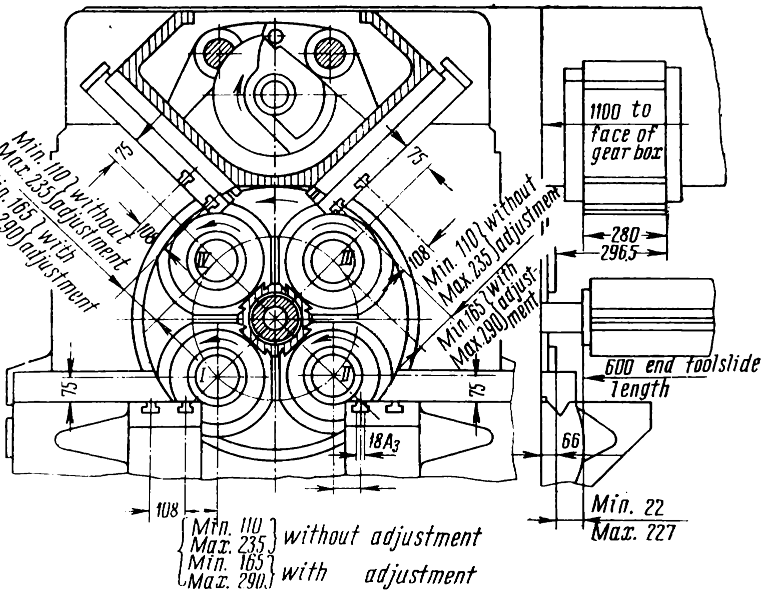


Fig. 199. Arrangement of slides and working positions on the heavy-duty four-spindle automatic bar machine, model 1290.

§ 108. MULTIPLE-SPINDLE VERTICAL SEMI-AUTOMATIC CHUCKING MACHINES

Several models of multiple-spindle vertical semi-automatic chucking machines are manufactured in the Soviet Union (Tables 31 and 32).

Table 31

Brief Specifications of Multiple-Spindle Vertical Semi-Automatic Chucking Machines of the Progressive-Action (Multiple-Station) Type

Model	Number of spindles	Diameter of workpiece accommodated, mm	Spindle speed range, rpm	Motor power, kw	Approx. weight, tons
1282	8-spindle	200	55 to 500	20 to 23	18
1A283	6-spindle	300	26 to 233	20	13
1284	6-spindle	400	21 to 184	20	14
1284-Б	8-spindle	400	32 to 237	23 to 40	20
1285-Б	8-spindle	500	12.5 to 113	28 to 40	22
1283	6-spindle	320 250	45 to 800 55 to 1,000	55 to 75	24 22
1283	8-spindle	320 250	45 to 800 55 to 1,000	75 to 100	28 26

Table 32

Brief Specifications of Multiple-Spindle Vertical Semi-Automatic Chucking Machines of Continuous Type

Model	Number of spindles	Max. workpiece diam accommodated over outer column, mm	Spindle speed range, rpm	Motor power, kw	Approx. weight, tons
128	6-spindle	400	92 to 698	48	17.2
1285	6-spindle	500	27 to 168	50	16
1295	6-spindle	500	19 to 140	55	21.4
			27 to 269		
1272	6-spindle	125/250	65 to 1,440	50 to 140	55

Multiple-spindle vertical semi-automatics may be classified: according to their principle of operation into multiple-station progressive-action and continuous types, according to the number of spindles (6 or 8), and according to the maximum workpiece diameter accommodated (ranging from 200 to 800 mm).

The general arrangement of the units, the construction, gear trains, setting-up methods and the controls of these semi-automatics are unified to a considerable extent.

Setting up these semi-automatics is a time-consuming job and, therefore, their application is effective only for mass production. They are extensively employed in automobile and tractor plants, as well as other mass production enterprises.

§ 109. MULTIPLE-SPINDLE VERTICAL SEMI-AUTOMATIC CHUCKING MACHINES OF PROGRESSIVE-ACTION TYPE

These semi-automatics are multiple-station machines and have a very high productive capacity. They are used in machining heavy forgings or castings. As a rule, the following operations are performed: straight turning and facing, boring and recessing, reaming, core-drilling and spot-facing. Threading is more seldom done as is multiple-drilling with special attachments.

The machining method for these semi-automatics is the same as for the horizontal multiple-spindle semi-automatics, models 1240-6П and 1265П (see § 105). The time required to make one piece is the sum of the machining time at the most time-consuming (limiting) position plus the time required for idle motions (carrier indexing, locking, etc.). The work is loaded and unloaded during operation and this has no effect on the rate of production except when it takes more time than the longest operation element.

Multiple-spindle vertical semi-automatics are extremely rigid in design. They comprise the following principal units: base, carrier with spindles, column and toolslides, feed works base with speed and feed gearboxes, main drive, and reducing gear.

§ 110. NEW POWERFUL EIGHT-SPINDLE VERTICAL SEMI-AUTOMATIC PROGRESSIVE-ACTION CHUCKING MACHINE, MODEL 1283

The eight-spindle vertical semi-automatic, model 1283 (Figs. 200 and 12) is designed for chucking operations in rough and finish machining of components, in large-lot and mass production. The principal specifications are listed in Table 31.

This semi-automatic has 8 positions or stations. One is the loading position where the blank is loaded into a chuck; the other seven are working positions. If double-indexing is applied, the carrier indexes through 90° each time and two pieces are finished at each indexing.

The machine may operate on either a semi-automatic or on an automatic cycle. In the latter case, an automatic work handling device must be installed. The model 1283 has the following general arrangement:

The column and carrier are mounted on the base. The hydraulic unit, coolant pump, chuck control pedal, and rotary master switch

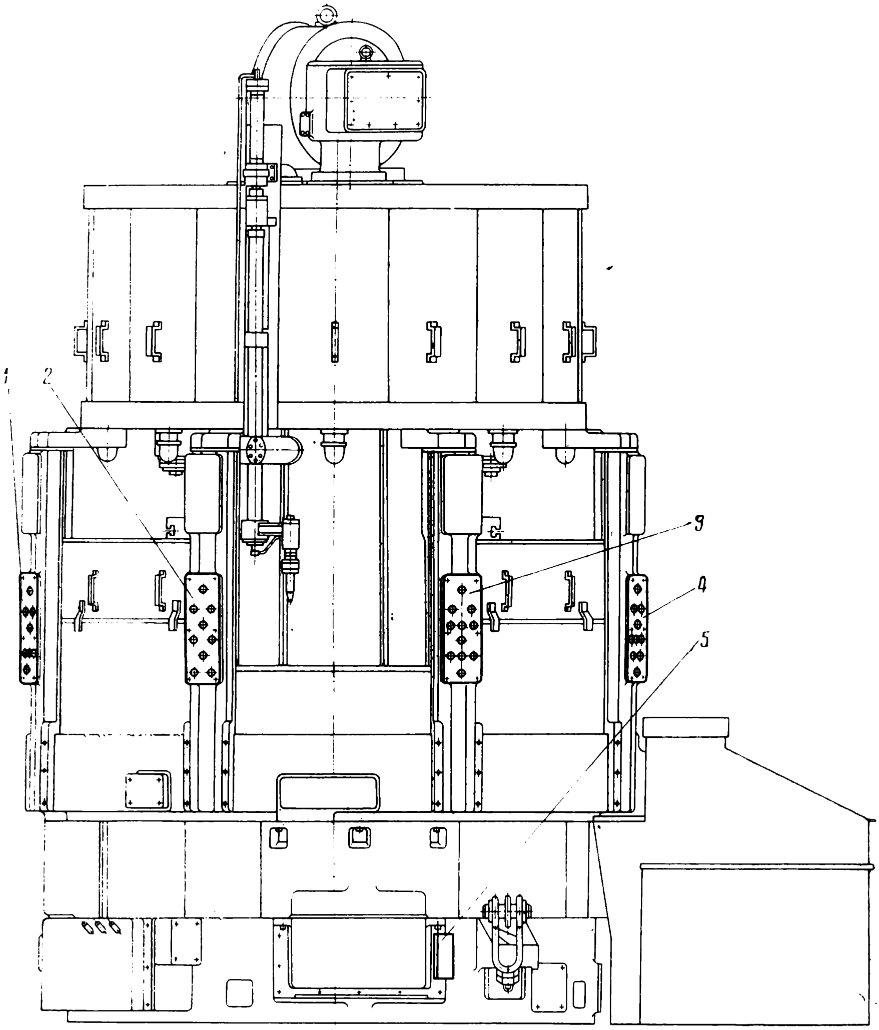


Fig. 200. Powerful eight-spindle vertical progressive-action semi-automatic chucking machine, model 1283.

1—control panel for working positions, *2*—control panel of first working position, *3*—control panel of loading position, *4*—control panel of the seventh position, *5*—chuck control pedal.

of the loading device are mounted on external pads around the base.

The spindle brake, synchroniser, carrier clamping cylinder, and the hydraulic system piping are arranged inside the base.

The uprights which hold the coolant ring are also fastened on the base.

The mechanism for indexing and locking the spindle carrier is located between the base and the coolant ring.

The feed works base is mounted on the column; it carries the feed and speed gearboxes. Rotary master switches and work lights are secured to bosses under this base.

The drive base is mounted on the feed works and carries the reducing gear, main drive motor, automatic loading mechanism bracket, etc.

The tool heads with individual drive are mounted on the faces of the column. The type of head is selected to suit the given setup.

The semi-automatic is controlled by an electrohydraulic system through rotary master switches. The chucks are operated by hydraulic action. The carrier is locked on a large radius, a feature providing high accuracy in operation.

A Geneva wheel mechanism indexes the carrier from position to position.

The availability of two ranges of spindle speeds and tool feeds at any position enables the rate of production to be increased.

Two different feeds in each cycle may be set up for each position. This feature extends the processing capacity of the machine. The toolslides are fed by a power screw and nut. They are of rigid design and travel on hardened ways.

Starting, setting-up, and adjustments. To set up the model 1283 semi-automatic, it is necessary to turn the selector switch, on the loading position panel, to the "Setting-Up" position from the "Semi-Automatic" position and to start the hydraulic pump motor by pressing the "Hydraulic Unit" push button. A few seconds later, the main drive motor is switched on by pressing the corresponding push button. Then the push button "Spindle-Start" is pressed on the first position panel to start spindle rotation which is in the counterclockwise direction.

The coolant pump motor is switched on by pressing the "Coolant-Start" push button on the loading position panel. After this, operation in the cycle is checked by an idle run.

A rotary master switch controls the operating cycle at each working position. It is set up in the following manner: to set the rapid approach lengths of the toolslides, the screws of the LSF dial are loosened $^1/_4$ or $^1/_2$ turn and this dial is set so that its index line coincides with the required value on the LSS dial. Then the screws are retightened. The other dials are set up in a similar manner.

Toolslide operation is checked by means of the push button "Rapid Approach", "Working Feed", and "Rapid Return" on the panel of the first working position. Pressing the "inching" push button "Rapid Approach" starts slide travel downward from the upper initial position for the length of the approach, which is determined by the master switch of the given slide. As soon as the master switch is tripped, slide travel ceases even if the "Rapid Approach" push button is held down. Further slide travel is possible only after turning the switch "Working Feed" to the "On" position. This starts the first (coarse) working feed.

When the master switch is tripped again, the slide automatically changes over to the second (fine) feed (if such is provided for in the given position). At the end of the travel, the slide stops. At this, the "Working Feed" switch is turned to its "Off" position and the inching push button "Rapid Return" is pressed. The slide rapidly returns to its upper initial position and stops after going through its complete cycle of motions.

Besides checking the slide operating cycles, it will be necessary to check the operation of the synchroniser in the main drive. The "Spindle-Start" and "Spindle-Stop" push buttons are used for this purpose. They are pressed alternately several times to engage and disengage the synchroniser. Spindle rotation will indicate whether the synchroniser is in proper order. The synchronisers at all the other positions should be disengaged at this time, otherwise pressing the "Spindle-Start" push button in the given position will start spindle rotation at all the other positions too.

After checking operation at each position separately, operation of the machine as a whole is checked.

Three operating cycles are available on the semi-automatic:

1. automatic cycle with a loading device;
2. semi-automatic cycle with a loading device;
3. semi-automatic cycle without a loading device.

The required cycle is selected by the "Automatic-Semi-Automatic-Setting-Up" switch on the loading position panel and the switch "On-Setting-Up-Off" on the first working position panel.

An automatic cycle is started by pressing the push button "Indexing" after which the carrier is indexed and then locked. This is followed by rapid approach of the slides and, simultaneously, the cycle of the automatic handling (loading) device. Upon the completion of the operating cycles of all the slides, and the unloading and loading of the work, the carrier is indexed automatically and the cycles will repeat one after another.

To repeat the cycle in semi-automatic operation, it will be necessary to press the "Indexing" push button again at the end of each cycle. If the loading device is switched off, the chuck will automatically open (after a definite time delay); it can be closed by depressing a pedal.

The operation of the automatic handling device is checked and set up in a setting-up cycle by pressing the "inching" push button of the master switch at the first working position. A signal lamp indicates that this device is in its initial position for operation.

§ 111. MULTIPLE-SPINDLE VERTICAL SEMI-AUTOMATIC PROGRESSIVE-ACTION CHUCKING MACHINES, MODEL 1282 AND OTHERS. GEAR TRAINS. STARTING THE SEMI-AUTOMATIC

Construction. The base is a one-piece, highly rigid casting of cylindrical form. Inside, it is divided into two isolated compartments, serving as reservoirs for lubricating oil and cutting fluid. Two pumps, gear type for lubrication and centrifugal type for coolant, are mounted in the base. The column is fastened rigidly on the base casting. The lower part of the column is a truncated cone, while the upper part is a polygon with the number of faces corresponding to the number of spindles or positions. Ways are fastened with screws to all but one face of the column.

The column contains the automatic carrier indexing mechanism. At the end of each cycle, when the tool slides have returned to their initial positions, this mechanism indexes the carrier with the work spindles. The carrier is located on the tapered section of the column and is supported underneath by an adjustable ball bearing. A crank mechanism effects periodic carrier indexing.

The spindle speeds and slide feeds at the various positions are set up independently of the other positions and in accordance with the operation sheet. No spindle drive is provided at the loading position and therefore the finished workpiece is removed and a new blank is loaded with the spindle held stationary.

The feed works base is mounted on the column and holds the speed and feed gearboxes, friction clutch, and operating controls. The unified speed and feed gearboxes enable speeds and feeds to be set up with change gears, independently for each position. The central component of these gearboxes is a cam drum for slide feed. The drum is driven by a vertical shaft from either the working or idle (rapid) rotation gear trains.

The feed cams are fastened by screws to the drums and form endless curves (slots) with two helical branches. The curves with a small helix angle provide downward working feed of the slides; the steep branches are for rapid return to the upper position.

The cam rolls with their rods are coupled to racks which, in turn, are linked to the toolslides (Fig. 201). The couplings allow a 150 mm adjustment along the rods. This means that the final position of the toolslides may be adjusted by that amount to suit the work size and the operation to be performed.

There are different types of tool heads available. A standard cross compound head provides for vertical movement downward and a horizontal movement from right to left. The standard universal head may additionally have slide movement from left to right or at any angle. All slides are balanced by counterweights.

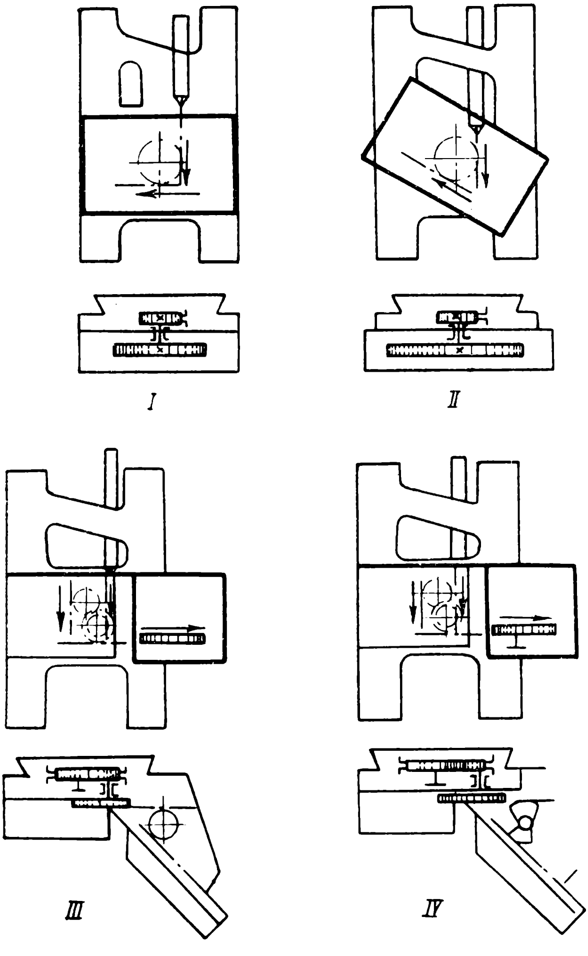


Fig. 201. Tool heads for multiple-spindle vertical semi-automatics.

I — standard cross compound head (vertical and horizontal movement), *II* — standard universal head, *III* — standard double purpose head (vertically downward and outward, travel ratio 1 : 1), *IV* — standard double purpose head (vertically downward and outward, travel ratio 2 : 1).

An automatic cycle of toolslide operation consists of rapid approach, working feed, and rapid return. The cycle is set up with the required lengths of rapid approach and working feed by positioning trip dogs on a timing disc. The sum of these two movements is always equal to 200 mm. The working feed may comprise lengths of vertical and horizontal travel. The proper relation between them is achieved by setting a stop which opens the lock.

The gearing systems of this range of multiple-position semi-automatics are similar to that of model 1282, shown in Fig. 202 or that of model 1283 (Fig. 203).

From the electric motor *27*, mounted on the top of the machine, rotation is transmitted through spiral bevel gears *26* to the vertical shaft which passes through a hollow shaft comprising two independent sections.

A gear, mounted on the hollow shaft, transmits rotation to a central gear mounted freely on its shaft. Through gears, also mounted on vertical shafts, the central gear drives the spindles and feed works for each working position. Each spindle is driven through the change gears *23*, a vertical shaft, sliding gear and the spindle gear *30* mounted on the spindle *14*. Since the carrier and spindle index periodically, the sliding gear *29* is shifted out of mesh with gear *30* on the spindle each time before indexing takes place. The sliding gear is returned to its working position by spring action. During the time these gears are engaged and disengaged, the main drive is disengaged by means of the disc-type friction clutch *2*, which transmits rotation to the hollow shaft. The friction clutch *2* is controlled by a cam on the upper drum *25*. Band brake *3* is provided for rapidly stopping the spindle.

The carrier is indexed by means of the control shaft *9* which is driven continuously from a gear on the lower end of the vertical shaft. The control shaft carries the upper and lower control drums, *25* and *10*.

The control shaft is centrally located. Gear *28*, mounted on its lower end, meshes with a second gear *28*, having the same number of teeth, and transmits rotation to the index crank *12* which actuates the indexing arm *13*. The right-hand slot of the arm is guided by the central shaft *9* while the slot at the left-hand end engages a roll on the end of the spindle. When any of the spindles *14* reach the loading position, the left-hand slot of indexing arm *13*, which finishes its movement under the action of crank *12*, passes over the spindle roll. Then the arm, rotated by the crank, indexes the carrier through 60° for a six-spindle machine or 45° for an eight-spindle model. Carrier indexing takes place during one revolution of central shaft *9*. This also corresponds to one revolution of gears *28* and takes about 3 seconds.

The working speed is imparted to the feed cam drums *19* of the slides by worm gearing, transverse shafts, change gears *21*, clutch *20*, and a second worm gearing arrangement. The cam drum *19* rotates at high speed for the rapid idle movements. In this case, it is driven from the vertical shaft through helical gearing *24*, high-speed claw clutch and the worm gearing of the slow motion gear train.

Cam drum speed is changed over by the timing disc *18* which is rigidly mounted on the shaft of drum *19*. Four trip dogs are arranged on the disc; the first changes over from rapid to slow rotation,

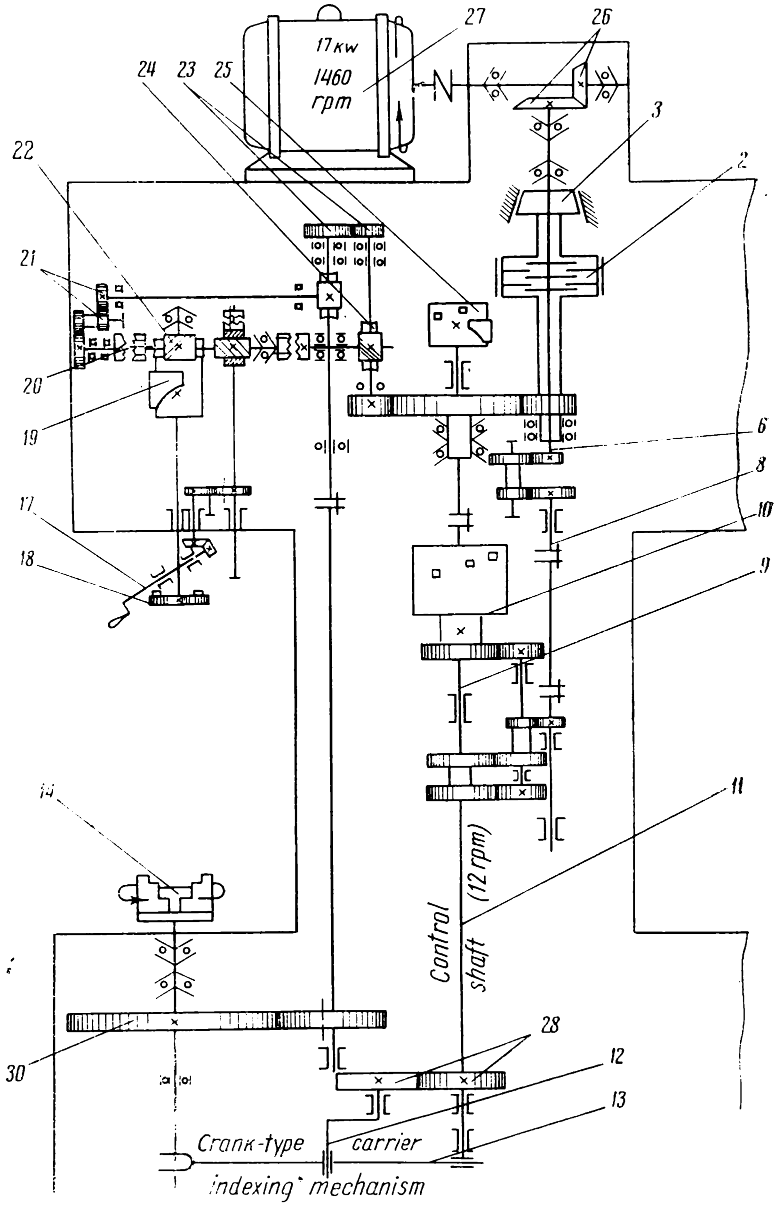


Fig. 202. Elementary gearing diagram of a multiple-spindle vertical semi-automatic.

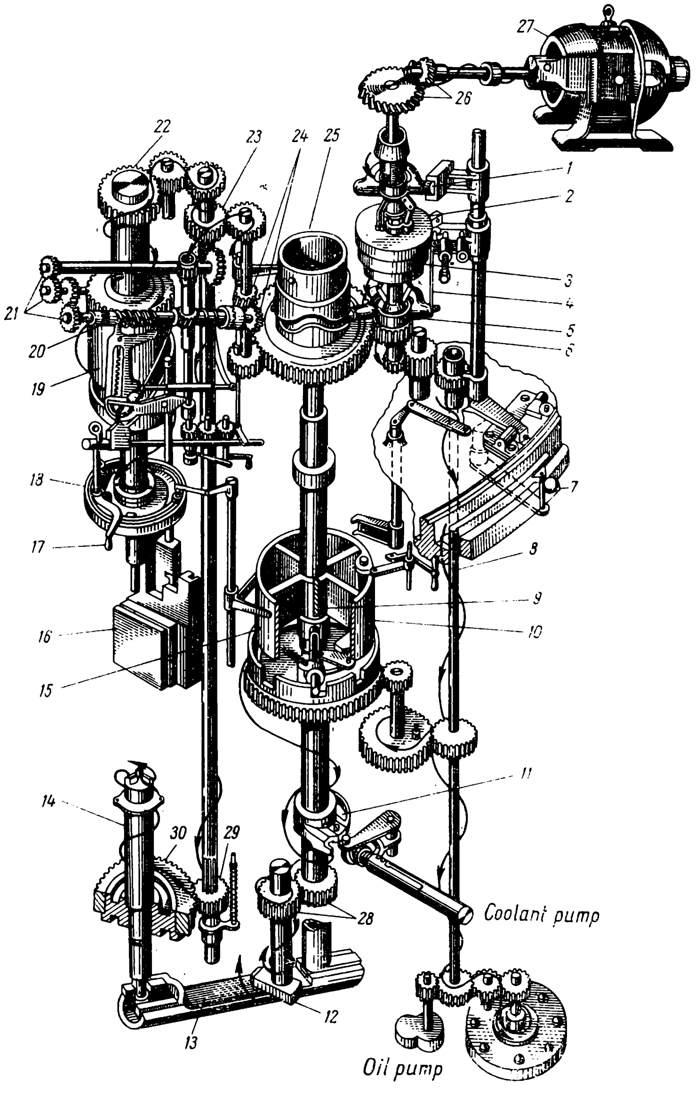


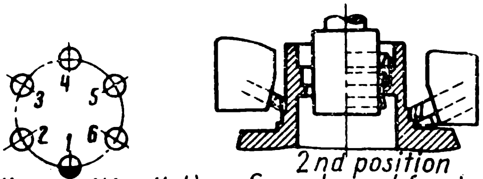
Fig. 203. Isometric gearing diagram of a multiple-spindle vertical semi-automatic.

1—starting clutch fork, *2*—clutch case, *3*—band brake, *4*—tie-rod actuating the band brake, *5*—fork for automatic engagement of the clutch, *6*—manual engagement shaft, *7*—starting ring, *8*—pump and lower control drum drive shaft, *9*—manual locking lever of control drum, *10*—lower control drum for spindle rotation, *11*—locking mechanism, *12*—index crank, *13*—carrier indexing arm, *14*—spindle, *15*—lock for preventing drum rotation, *16*—tool head, *17*—lever for engaging working feed or idle movements and for stopping the feed drum (neutral position), *18*—timing disc, *19*—feed drum, *20*—working feed clutch, *21*—feed change gears, *22*—tool rotation change gears (for drills and boring bars), *23*—spindle change gears, *24*—helical gearing, *25*—upper control drum for spindle rotation, *26*—spiral bevel gears, *27*—main drive motor, *28*—index crank gearing, *29* and *30*—spindle drive gears.

the second from slow to rapid rotation, the third controls the initial position of the toolslide, and the fourth sends a work signal which permits carrier indexing by the control drum *10*.

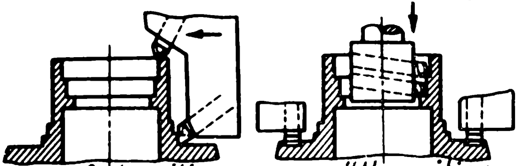
For setting up the semi-automatic, provision is made for manual feed of the toolslides by means of the lever *17* when the clutch is engaged. A lever is provided for engaging the upper clutch of the helical gears and a crank for rotating the cam drum through spur, helical, and worm gearing arrangements. Upon engagement of the hand feed by means of the clutch, linked through interlocking levers, the power feed is automatically disengaged.

Multiple-spindle vertical semi-automatics present extensive possibilities for setting up the most effective cutting speeds and tool feeds. Another feature, of great advantage in comparison with other types of multiple-spindle semi-automatics, is that the spindles may have a speed set up for each position, independent of the other positions. The tool head installed may provide a large variety of working movements, also with independent feeds. The tool may be fed longitudinally, crosswise, or at any angle to the work axis. Curvilinear tool movement is also possible. A tooling layout for a vertical semi-automatic is illustrated in Fig. 204.



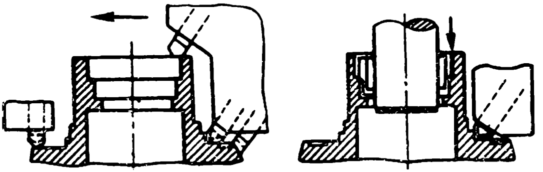
Loading position (1st)

2nd position
Speeds and feeds n=106 rpm
S=0.39 mm/rev



3rd position
Speeds and feeds n=76 rpm
S=0.46 mm/rev

4th position
Speeds and feeds n=106 rpm
S=0.39 mm/rev



5th position
Speeds and feeds n=76 rpm
S=0.46 mm/rev

6th position
Speeds and feeds n=77 rpm
S=0.43 mm/rev

Fig. 204. Tooling layout for the six-spindle vertical progressive-action semi-automatic.

If the workpiece does not require a large number of operation elements, multiple-spindle semi-automatics may be set up for double indexing (parallel-progressive principle). In this case, there will be two loading positions and two pieces will be finished after each cycle. The same or a different series of operation elements may be performed at the two groups of positions.

Starting the semi-automatic. After switching on the motor by means of a special ring-type pilot wheel, the coolant and lubricating pumps begin to operate. Oil is delivered upward to the filter and further to the distributing tank from where it is fed by gravity through tubes to the points of lubrication. If the lubricating system becomes clogged up at any point, the machine will be automatically switched off. The cutting fluid is delivered to an annular reservoir arranged around the carrier, and from here to each working position.

When lubricant and cutting fluid is being delivered at the required rate of flow, the semi-automatic is started by means of the clutch shift ring which is arranged overhead at a convenient height and enables the machine to be started or stopped from any position.

After firmly clamping the blank, the locking lever is withdrawn with a handle. This releases the locking devices, the control drum begins to rotate and the semi-automatic operates on its normal cycle.

Special attachments may be installed on these machines for drilling several holes simultaneously or for tapping. Special multiple-spindle heads are used for such drilling. They are geared and have a central driving shaft. External thread is cut with self-opening die heads.

§ 112. MULTIPLE-SPINDLE VERTICAL SEMI-AUTOMATIC LATHES OF THE CONTINUOUS TYPE

Several models of high-production continuous-type vertical semi-automatic lathes are made in the U.S.S.R. They differ from each other in the number of spindles (six or eight), workpiece capacity (up to a maximum diameter of 800 mm) and motor power (up to 150 kw). They are designed for turning work held between centres or in a chuck. Certain models are equipped with automatic loading and unloading devices. Both roughing and finishing operations are performed.

These semi-automatics operate on the following principle: each spindle, which accommodates and drives a workpiece, has its own toolslides. Spindles and slides are arranged on a continuously indexing outer column and carrier. The operating cycle is planned so that a workpiece is finished in each spindle in the time that it takes the carrier and outer column to make one revolution. The workpieces are finished when they reach the loading position where they are removed and a new blank is loaded.

Since the carrier and outer column index continuously, the drive is designed so that spindle rotation is automatically disengaged when a spindle enters the loading zone and the toolslides return to their initial positions.

Continuous-type semi-automatics are actually a combination of six or eight single-spindle lathes having a common drive and controls. The outer column, having six or eight faces for installing tool heads (one on each face), is mounted together with the spindle carrier on the inner column.

The spindles are rotated by the main driving shaft and toolslides are operated by a single cam mounted on the cam drum at the top of the machine. *The work machining cycle at each spindle is performed in one revolution of the carrier, and is divided into two stages.*

The first stage of the cycle consists of idle movements which take place when the spindle passes through the loading zone. During this time, spindle rotation is disengaged, the toolslide with the tools returns rapidly to its upper position, the operator removes the finished work and clamps a new blank (or mounts it between centres), the toolslides rapidly approach the work, and the spindle begins to rotate again. In this type of semi-automatic, all operations, except for removing the finished work and loading a new blank, are performed automatically. The provision of an automatic handling device will automate loading and unloading as well.

The second stage consists in continuous machining during a carrier otation of 360° — 60°=300° for six-spindle models and 360°—45°=315° for eight-spindle models.

§ 113. SIX-SPINDLE VERTICAL CONTINUOUS-TYPE SEMI-AUTOMATIC LATHE, MODEL 1285

This semi-automatic (Fig. 205) comprises the base, inner column spindle carrier and outer column, tool heads, spindle drive, and carrier rotation drive (feed drive). The base has two compartments; one is a reservoir for lubricant and the other for cutting fluid. The central inner stationary column is rigidly mounted on the base. It serves as a pivot about which the hexagonal outer column and spindle carrier rotate. They are supported by an antifriction bearing mounted in the lower flange of the inner column. The outer column is a machined hexagonal casting with six tool heads mounted on its six faces. A housing with tie-rods is mounted on the top of the inner column. The tie-rods actuate the toolslides and are controlled by the cams of the stationary cam drum (Fig. 206).

Special sleeves, carrying the spindles, are mounted in the carrier.

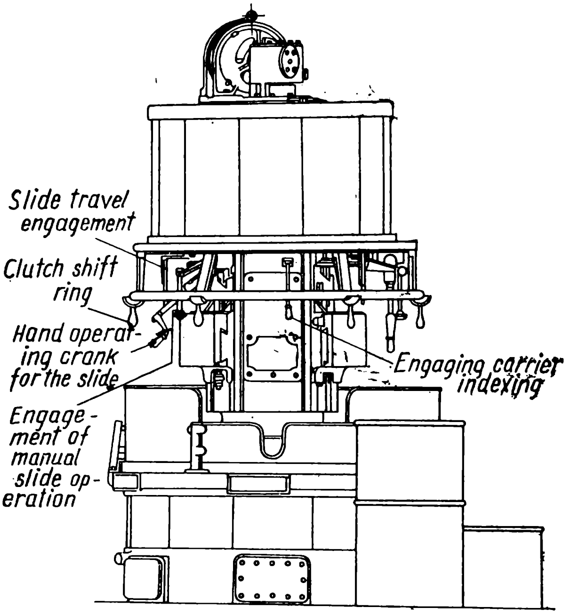

Slide travel engagement
Clutch shift ring
Hand operating crank for the slide
Engagement of manual slide operation
Engaging carrier indexing

Fig. 205. Six-spindle continuous-type vertical semiautomatic, model 1285.

The chucks, when used, are hydraulically operated to facilitate and speed up opening and closing. When each spindle reaches the loading zone, the finished workpiece is automatically unclamped; the new blank is automatically clamped when the spindle leaves this zone. These movements are obtained by delivering oil periodically to one or the other end of the hydraulic cylinders. The work clamping and unclamping cycle is controlled by pilot valves which are operated by a cam during carrier rotation.

The spindles (Fig. 207) with their driving gears run in tapered roller bearings of the upper support and a radial ball bearing of the lower support.

The bearings are lubricated with oil delivered under pressure by the hydraulic system. A cylinder, arranged under each spindle, has a piston rod which opens and closes the chuck through a drawbar (not shown in Fig. 207). Oil flow is automatically directed to the upper or lower end of the cylinder by a pilot valve which is controlled by a cam in the loading zone.

Tool heads comprise toolslides with cutting tools which travel on ways of the stationary saddles fastened to the faces of the outer column. Various types of tool heads may be installed such as: standard plain heads for vertical feed only and double-type with parallel-action angular slides.

Each toolslide is operated from the cams of a stationary drum on top of the inner column. Upon rotation of the carrier with the spindles and the outer column with the tool heads, the tie-rods of the slides move up and down in accordance with the curve and thus traverse the toolslides.

Setting up. The outer column and carrier are driven by a reducing gear with a separate motor (see Fig. 206). The reducing gear has

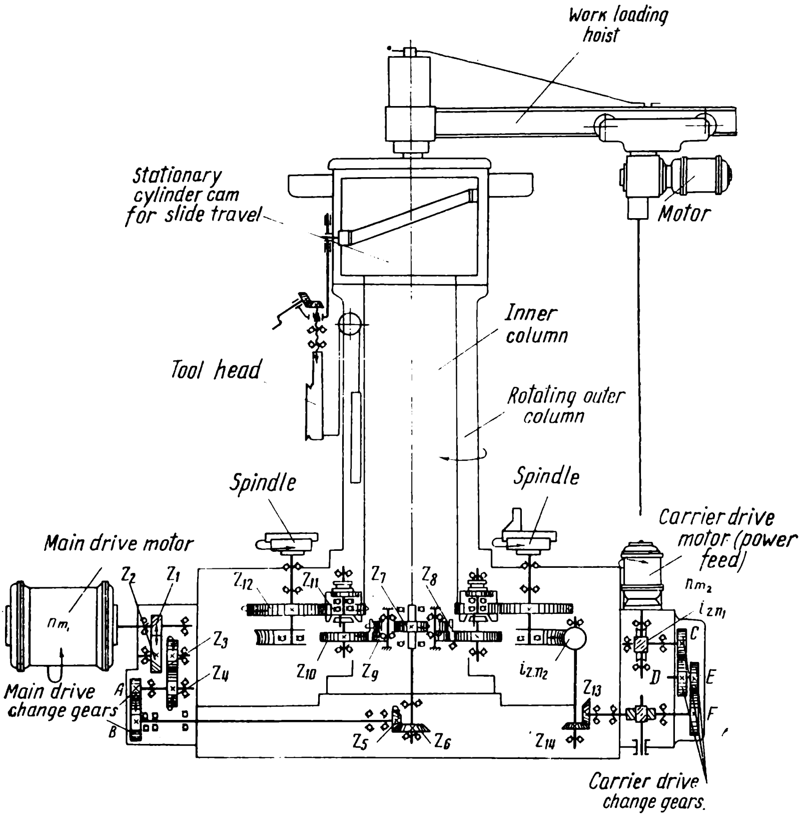


Fig. 206. Gearing diagram for the semi-automatic, model 1285.

$$n_s = n_{m_1} \times \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4} \times \frac{A}{B} \times \frac{25}{26} \times \frac{27}{28} \times \frac{Z_{11}}{Z_{12}} \text{ rpm},$$

$$n_{carrier} = n_{m_2} \times i_{w\,g_1} \times \frac{C}{D} \times \frac{E}{F} \times \frac{Z_{13}}{Z_{14}} \times i_{w\,g_2} \text{ rpm},$$

$$s_{long} = \frac{n_{carrier}\, t i}{n_s} \text{ mm/rev.}$$

$$v_{rapid\ slide\ traverse} = \frac{n_{carrier}\, t^1 i}{1,000} \text{ m/min}$$

in which $i_{w\,g_1}$ and $i_{w\,g_2}$ are the transmission ratio of the 1st and 2nd worm gearing arrangements.

t and t^1 are the leads of the working and idle movement cams in mm.

two pairs of change gears. Worm gearing is the last item in the gear train for carrier rotation. Setting up formulas are given under Fig. 206.

The rate of feed and length of travel is identical for all the toolslides. The cams on the drum are not changeable and therefore the speed of slide movement (rate of feed and rapid traverse) may be changed only by varying the speed of rotation of the carrier and outer column. This involves a corresponding change in the cycle time. Rapid approach and return speeds of the slides may differ in different setups and also depend on the cycle time. The toolslide

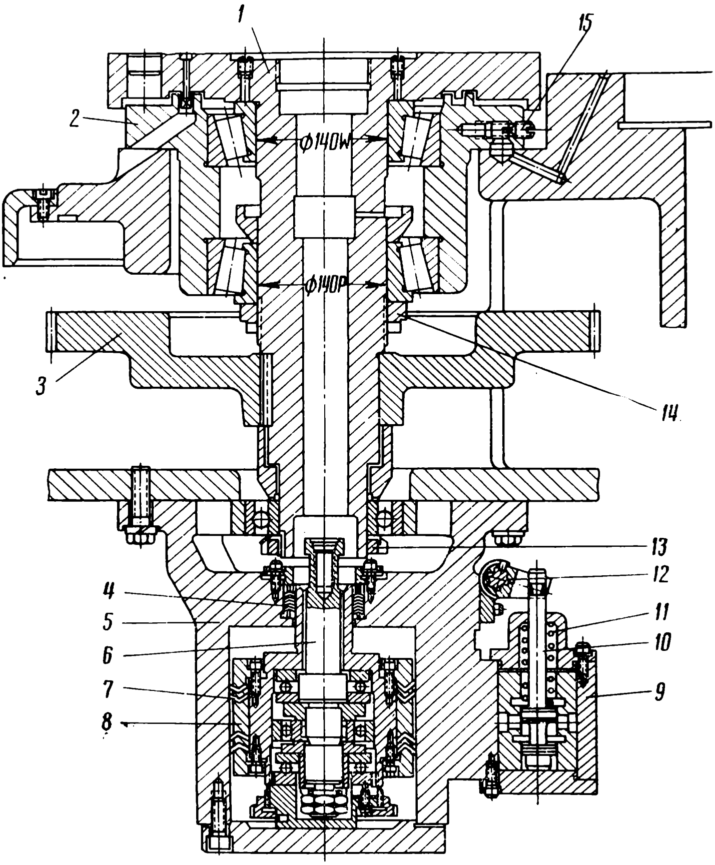


Fig. 207. Section through the spindle and hydraulic cylinder of semi-automatic, model 1285.

1 — spindle body, *2* — housing, *3* — spindle gear, *4* — packing seal, *5* — flange, *6* — shaft, *7* — grooves, *8* — insert, *9* — cylinder, *10* — valve piston, *11* — spring, *12* — spline shaft, *13* — washer, *14* — spacer, *15* — pin.

position may be adjusted manually through bevel gearing, a screw and a nut. All toolslides are balanced by counterweights.

The semi-automatic is controlled from a push button station on the control panel. A second push button station controls the electric hoist. The push button for switching off the hydraulic pump motor of the chucks also acts as an emergency stop push button. In starting, the hydraulic and lubricating pump motor is switched on first. After this, the spindle and carrier drive motors are switched on and last of all the coolant pump motor.

A special relay checks the pressure in the hydraulic chuck circuit. If this pressure drops below a preset value, the spindle and carrier drive motors are switched off.

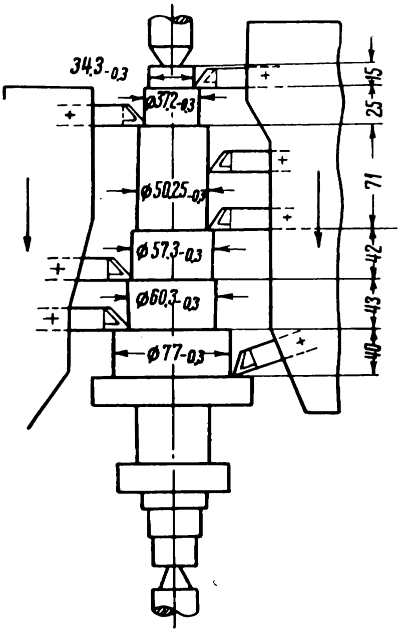


Fig. 208. Tooling layout for continuous-type semi-automatics.

A separate pipeline delivers cutting fluid (coolant) to the tools of each slide. Lubricant is delivered from the hydraulic system to the highest point of the machine from where it flows by gravity to the various points of lubrication. The tooling layout for each spindle of a continuous-type vertical semi-automatic is shown in Fig. 208.

§ 114. NEW MULTIPLE-SPINDLE VERTICAL CONTINUOUS-TYPE SEMI-AUTOMATIC AND AUTOMATIC LATHES, MODEL 1272

The model 1272 semi-automatics and automatics are of the continuous type (see Fig. 24) and are designed for turning work up to 250 mm in diameter and up to 750 mm long between centres or held in a chuck. The maximum length turned is 500 mm. Special setups may be designed for turning with hydraulic tracer-controlled toolslides. Automatic loading and unloading devices may be installed. The line and isometric gearing diagrams of this machine are illustrated in Fig. 209.

All toolslides have the same tooling. The number of workpieces machined at the same time is one less than the number of spindles since one spindle is being loaded. Machines equipped with automatic loading facilities have a cycle which differs slightly from that of semi-automatics. To facilitate automatic loading and unloading,

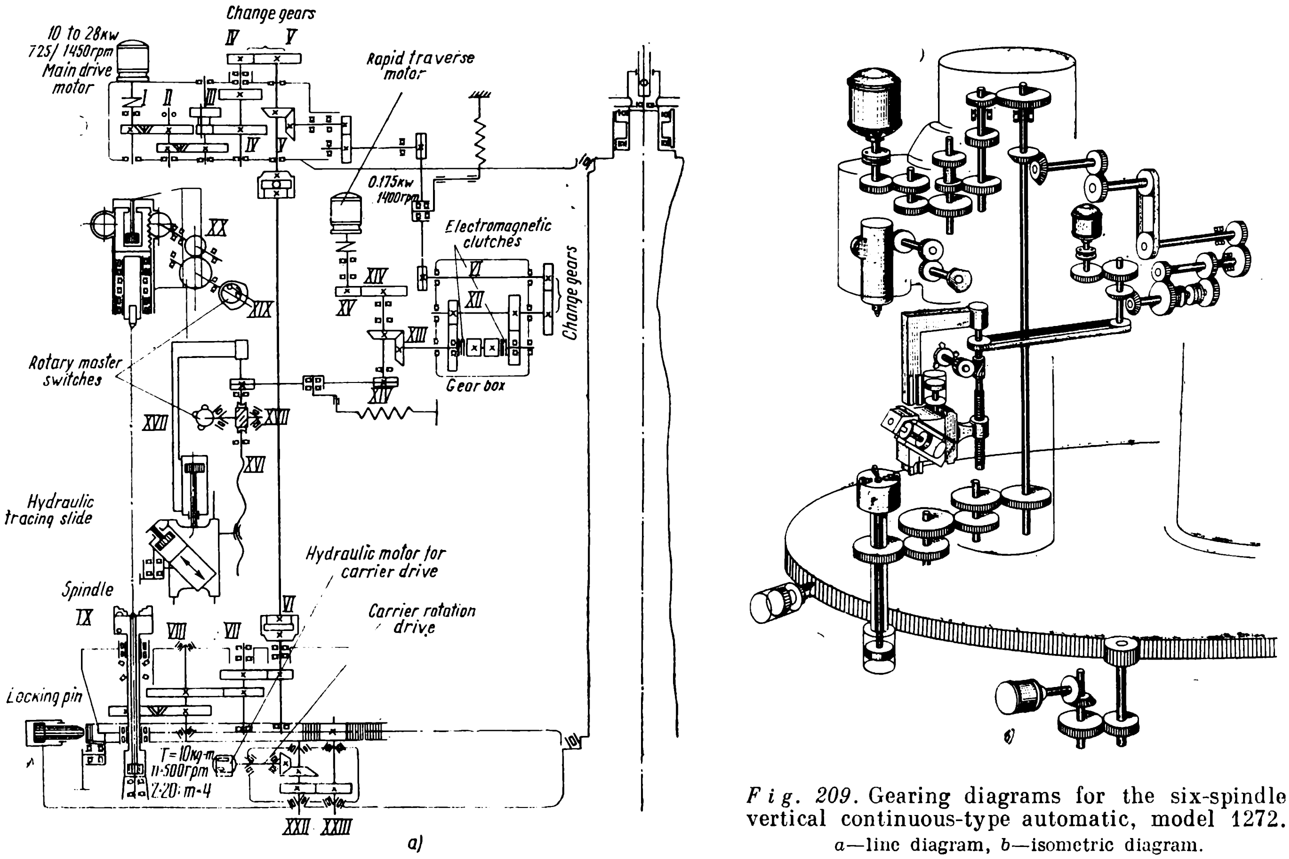


Fig. 209. Gearing diagrams for the six-spindle vertical continuous-type automatic, model 1272. *a*—line diagram, *b*—isometric diagram.

the carrier stops periodically, each time the next spindle reaches the loading position. Only the spindle at the loading position is disengaged during this time; machining continues on the other spindles.

Arrangement (see Fig. 24). The base is a trough-shaped casting used as a reservoir for the hydraulic system oil and carrying all the other units and mechanisms. The stationary inner column is mounted at the centre of the base; housings of the screw-type chip conveyers are located at the sides together with their drives. These housings also serve as coolant reservoirs. The coolant pump is located in the left-hand housing; the hydraulic pump—in the right-hand housing.

The carrier indexing and locking mechanism is arranged behind the base. The annular coolant pan with openings is mounted on the chip conveyer housings, indexing mechanism, and on a bracket, in front of the base. Vertically sliding shields with transparent windows are arranged between uprights attached to the annular coolant pan. The carrier with the spindle units and the outer column with the upper base rotate about the stationary inner column on tapered roller bearings.

The upper part of the spindle carrier is of tapered form to facilitate washing the chips into the coolant pan. The carrier is reinforced by ribbing and carries a ring gear underneath for the indexing drive. In carrier locking, a pin enters a tooth space of this same ring gear which runs on six pairs of rollers in addition to the bearings supporting the carrier.

The outer column connects the carrier to the upper base; its faces carry the longitudinal carriages. The upper base, attached to the outer column, mounts the speed and feed gearboxes and hydraulic control panel.

Cross feeding slides are mounted on the uprights between the carrier and upper base. The uprights also link the carrier to the upper base and form a highly rigid frame system consisting of the carrier, outer column, upper base, and uprights.

The main drive consists of the main drives for each spindle, powered by a separate motor, which is mounted on the speed gearbox of the corresponding position. Rotation is transmitted through a flexible clutch, a series of gears, countergearing, change gears, and a long-tooth claw clutch mounted on a shaft of the spindle unit in the carrier. All shafts run in antifriction bearings. The front spindle support consists of a double-row cylindrical roller bearing and two angular contact ball bearings. The lower support comprises a double-row roller bearing. Cylinders for chuck operation and their hydraulic collectors are located under each spindle.

All transmission and bearings are lubricated from a central force-feed system.

The machine is set up by shifting the countergearing as required and installing the proper change gears. If two-speed motors are used in the spindle drives, the spindle speeds may be doubled during the cycle.

Longitudinal carriage and its drive. The feed motion for each longitudinal carriage is obtained from the corresponding speed gearbox and is transmitted to the feed gearbox through a system of pulleys, V-belt drives, and gearing. Automatic change-over from one working feed to a second, one half of the former rate, is accomplished by electromagnetic clutches in the feed gearbox. A V-belt drive transmits rotation to a screw passing through a nut in the saddle of the longitudinal carriage. The upper bearing allows axial movement of the screw. The upper end of the screw bears against a pilot valve which controls the operation of the carriage feed hydraulic cylinder. In its rotation the screw moves axially in relation to its nut and depresses the pilot valve. The saddle is then fed by hydraulic action and the nut and screw leave the pilot valve. This stops saddle feed. This process goes on during the whole feed period.

The hydraulic tracer-controlled slide, arranged on the saddle at an angle of 60° to the spindle axis, operates during longitudinal feed of the saddle. Duplicating is done to a template.

Rapid traverse movements are powered by a separate motor.

The provision of electromagnetic clutches in the feed control train enables the feed to be periodically disengaged. These impulse feeds are used to break up the chips.

Work signals or commands for engaging the different types of feed are transmitted by a rotary master switch driven from the screw.

Infinitely variable saddle feeds in a range of 4 : 1 may also be provided. In this case, transmission ratio variation is due to spreading pulleys over which a V-belt runs. The halves of the pulleys are spread or drawn together by a drive consisting of a lever system and gearing and controlled from a cam on the carriage.

The cross slides are mounted on the vertical uprights.

The cross slides are traversed by a hydraulic cylinder controlled by a screw in conjunction with a pilot valve (similar to longitudinal carriage operation).

This screw is driven from a separate motor through change gears and worm gearing. Rapid screw rotation is powered from the same motor through bevel gearing and and overrunning clutch when an electromagnetic clutch is engaged.

This unit is available with either a single or double cross slide.

The tailstocks are mounted on uprights of the outer column unit and may be adjusted axially 300 mm. The tailstock spindle with the running centre may be extended and clamped hydraulically in the required position. Tailstock spindle movement is transmitted to a rotary master switch mounted on the tailstock.

The hydraulic collector is designed for delivering oil under pressure from the stationary to the rotating parts of the machine and for distributing oil to the various spindles. The hydraulic collector is mounted on the top of the inner column. Oil is delivered to i by piping passing inside the column.

The coolant collector serves the same purpose for the cutting fluid; it is mounted on the electrical collector.

The electrical collector is mounted on the hydraulic collector and serves to transmit electric power and work signals from the stationary to the rotary parts of the semi-automatic. As a safety measure, *no one should be allowed to open the guard of the electrical collector before switching off the power supply to the machine.*

The hydraulic control panels and the oil pipelines are above the upper base and are connected on one side to the collectors and on the other to the operative units. They control oil flow in the system.

The coolant pipelines deliver cutting fluid in the required direction and at the proper moment in the cycle. This system is controlled by solenoids and valves.

The carrier indexing mechanism consists of a hydraulic motor, bevel and spur gearing, and a gear which meshes with the ring gear under the carrier. Locking is effected by a hydraulic cylinder which advances a locking pin into a tooth space of the carrier ring gear.

The carrier is accelerated and decelerated during indexing by means of trip dogs, mounted on the carrier, which actuated a hydraulic throttle valve.

The lubricating system is of the centralised force-feed type, supplied from the hydraulic system. Throttle valves regulate the amount of oil feed to the various points of lubrication.

Coolant system. Cutting fluid from the chip conveyer housings, which serve as reservoirs, is delivered by a centrifugal pump to the top of the machine. Through the coolant collector, it is distributed to the working zones. Cutting fluid feed is turned on or off in the loading zone by a solenoid-controlled valve. A part of the cutting fluid cools the cutting tool while the rest is used to wash the chips from the carrier. The streams washing the carrier are regulated by closing slots. Pressure in the system should be at least 4 atm. Such a pressure is required for normal chip disposal.

The loading attachment (Fig. 210) consists of the loading device, transfer device, and the magazine, hopper, or conveyer. From the magazine, hopper, or conveyer, the blank is fed out to the trough of the transfer device in a horizontal position. The transfer device pushes the blank in a vertical position into one of the two grips of the automatic handling device. After this, the grips move toward the spindle with the free grip in front and the finished workpiece is grasped. Then the workpiece is lifted (to release it from the chuck), retracted, and swivelled about the axis of the handling device. This swivels the grip with the new blank to the side nearest the spindle. Then hydraulic action again advances the grips toward the spindle and the blank is set into the chuck with a downward movement. After the blank is clamped by the upper centre, the arm returns to its

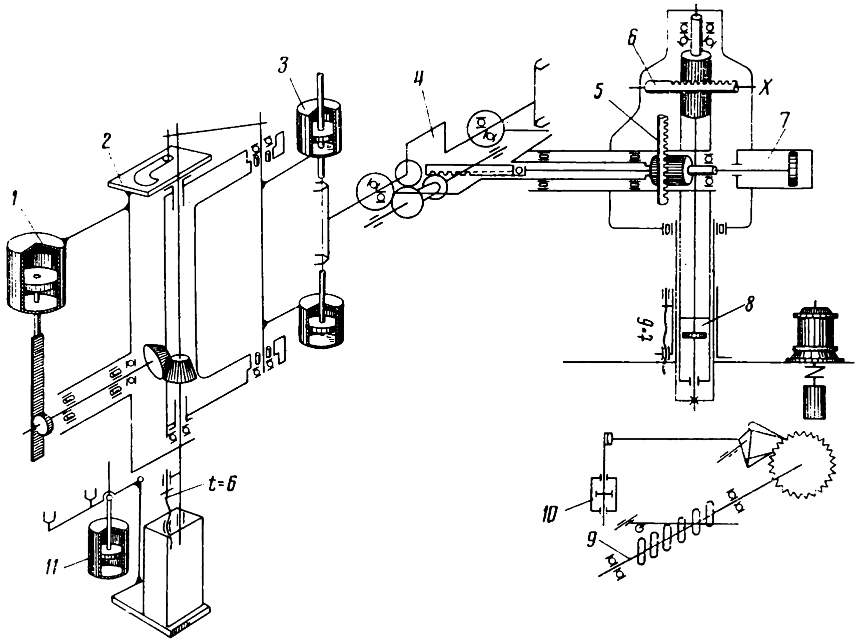


Fig. 210. Diagram of the loading attachment (automatic handling device) for model 1272.

1—trough raising and lowering cylinder, *2*—magazine, *3*—cylinders for advancing or retracting carriage centres, *4*—arm, *5*—head swivel about the axis of the arm, *6*—arm swivel, *7*—cylinder for swivelling the head about the axis of the grips, *8*—cylinder for raising and lowering the arm, *9* — rotary master switch, *10* and *11* — cylinders of the rotary master switch.

initial position, leaving the blank in the chuck and carrying the removed workpiece in the second grip.

At the end of the cycle, the finished workpiece is taken from the grips by the transfer device carriage and is passed to the gauging transmitter which checks the size and feeds back commands to readjust the cutting tools or to stop the corresponding spindle (active automatic inspection).

After measurements are made, the carriage again shifts the finished workpiece forward and releases it when a chute has been advanced under the work. The work drops on the chute and is removed to one side.

All movements of the loading attachment are hydraulically operated and powered from a separate hydraulic unit. The machine will operate with both automatic and with manual loading.

The control system is a combination of electromechanical and electrohydraulic types. Controls operate from rotary master switches or stops which actuate the corresponding control elements along the travel of the operative units.

Part Four

COMPLETE AUTOMATION OF PRODUCTION PROCESSES

CHAPTER I

AUTOMATION PRINCIPLES

§ 115. FUNDAMENTALS

Efforts made to further increase the productivity of labour have led to the development of automatic systems of machinery such as automatic machine tool "combines" and automatic transfer machines, as well as automated production lines, departments, and plants. It is evident that this involves the automation of work done, not only by a single machine tool, but by whole groups of machine tools and, in some cases, by departments and even plants.

Industrial organisation, in which the manufacturing process is entirely automated, is called *complete or comprehensive automation.*

Complete automation implies that the workpiece will be transferred automatically from one work position to another until it is completely finished.

If all the positions required to manufacture a given workpiece are concentrated in a single automatic or semi-automatic machine tool, such a machine will be called *machine tool "combine"*.

If the complete machining is performed consecutively on a series of machine tools linked together with an automatic work handling device and having common controls, such an arrangement is called an *automatic transfer machine.*

Automated production departments and plants comprise several transfer machines linked together by handling facilities.

Automatic transfer machines and automated plants were first developed and used in the Soviet Union whose precedency in this respect is indisputable.

Only one or two operators are required for control and maintenance of a transfer machine. These operators, however, must be highly skilled persons with a most comprehensive knowledge of each mechanism, conveyer, and machine tool employed in the automation of the manufacturing process. This condition is of prime importance in maintaining the efficiency of a complex automatic production process at the required level and in rapidly eliminating all trouble that may arise in the course of prolonged operation.

§ 116. LINES OF DEVELOPMENT OF COMPLETE AUTOMATION

Complete automation of production processes may be achieved along various lines. Automatic transfer machines, for example, may be composed of special machine tools. In this case, new machine tools must be designed for each new workpiece. Therefore, in the majority of cases, *automatic transfer machines comprise unit-type machine tools, which have been unified and standardised to a considerable extent.*

Another method involves the use of the machine tools, already installed in the given plant, by synchronising their operation and by equipping them with automatic magazine-feed and conveyer devices. The development of such automated production lines is of vital importance to industry since it enables complete automation, with its sharp increase in labour productivity, to be introduced in a short time and at a comparatively low expense.

Approximately, one-third of all machine tools used in the U.S.S.R. are lathes and, among machine tools with high automaticity, about one half are semi-automatic and automatic lathes. This explains *why such attention must be paid to the complete automation of lathe operations on existing machine equipment.*

The principal requirements, made to the design of lathes that are to be built into automatic production lines (including transfer machines), are the convenient approach, loading, unloading, and further transfer of workieces, high reliability in operation of all mechanisms and devices, and chip disposal without the participation of operators or other help.

General-purpose machine tools, which may operate as independent units, or may be built into a transfer machine (see Figs. 24, 74 and others), have been developed in the U.S.S.R. in late years.

§ 117. TYPES OF AUTOMATIC TRANSFER MACHINES

Automatic transfer machines may be designed in accordance with several systems (Fig. 211). The first is the direct-flow type in which all units (machine tools) are rigidly linked together and in which the workpiece is completely machined after being transferred consecutively from station to station (Fig. 211 *a*).

Advantages of such transfer machines are the lesser amount of mechanisms, less floor space occupied, and the rapid transfer of each given workpiece from station to station.

Automatic transfer machines, comprising several automated sections (Fig. 211 *b*), have automatic storage or "banking" facilities with reloading devices between the sections. If one section is stopped for any reason, the remaining sections may continue operation for a certain period of time which is usually sufficient for ordinary

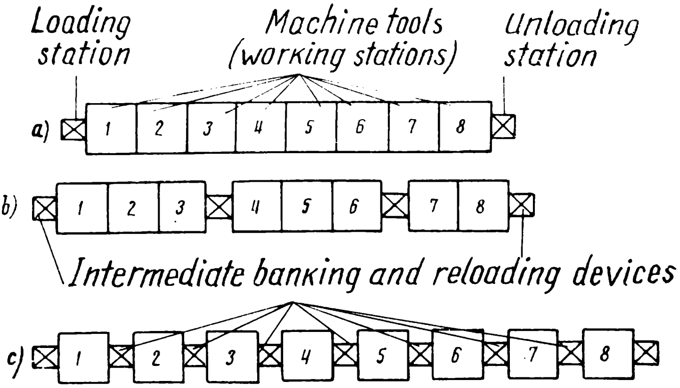

Loading station
Machine tools (working stations)
Unloading station
a)
1
2
3
4
5
6
7
8
b)
Intermediate banking and reloading devices
c)

Fig. 211. Types of automatic transfer machines.

repairs. The production capacity of this second type is higher than that of direct-flow models but they are somewhat more complex in design and occupy more floor space.

The last type of automatic transfer machine (or more exactly, automated production line) (Fig. 211 *c*) consists of machines linked together by storaging and magazine-feed devices. Each machine tool in the line may continue operation even if all the others are shut down for some reason for a short time.

Automated lines of this type have a number of magazine-feed devices equal to the number of machines or stations and production losses may be due not only to troubles in the machine tools but in the magazine-feed devices as well. The latter are usually complex in design and expensive.

Complete automation units, machine tool "combines", and automatic transfer machines are a further development of multiple-position machine tools.

§ 118. FEATURES OF AUTOMATIC TRANSFER MACHINES

The main feature of an automatic transfer machine is that the workpiece must be produced in the given quantity and of the specified quality without the direct participation of an operator. Consequently, the manufacturing process must conform to the following principal requirements:

1) the time required for the operations at each station must be equal, or nearly so, for a direct-flow type of machine;

2) the cutting tools applied on automatic transfer machines must be simple enough in construction and must possess high tool life insofar as cutting capacity and size maintenance are concerned;

3) the units of equipment must be simple in design, reliable, and highly productive; they should be convenient in maintenance;

4) the machine tools must be designed so that they may be quickly repaired and retain their accuracy over a long period of operation;

5) the cost of the automatic transfer machine and its operation must be economically feasible, i. e., it should provide a substantial increase in the productivity of labour.

Work-conveying in an automatic transfer machine may be of the pass-through type or the conveyer may be at one side or even of the overhead type. The pass-through type is the most efficient method but is not always feasible and often the conveying system is arranged overhead (see Fig. 215) or at one side (see Fig. 214). In these cases, additional devices are required to load and unload the work at each station (Fig. 215 *b* and *c*).

Lathes, built into an automatic transfer machine, are loaded by means of a transfer bar conveyer, automatic work handling devices (see Fig. 82) and transfer devices (Fig. 215 *b*). Work loading may be performed with ordinary attachments used on automatic and semi-automatic lathes only if each machine has a magazine-feed device.

Automatic inspection of the work after certain operations, as well as automatic inspection of the finished workpiece, has been widely applied in the design of up-to-date automatic transfer machines.

§ 119. TRANSFER MACHINE CONTROLS AND THEIR RATE OF PRODUCTION

The control systems of automatic transfer machines and automated production units must provide for the following modes of operation: automatic, semi-automatic, and setting up. Separate controls are required for the various machine tools, machinery, and mechanisms. Rapidly acting trouble-shooting facilities should be provided in the machine tool systems.

The rate of production of an automatic transfer machine is determined by the cycle time. *The cycle time of a transfer machine is the period of time between the output of successive finished workpieces or sets of workpieces (for multiple-flow arrangements).*

The computed cycle-time in minutes is determined from the formula:

$$T_{ct} = T_{c_{max}} + t_{uc} + t_{tr} + t_{lc}$$

in which $T_{c\,max}$ is the cycle time of the limiting machine tool or unit in minutes;

t_{uc}, t_{tr} and t_{lc} are the time in minutes required for unlocking the conveyer, transferring the workpiece to the next station, and for locking the conveyer again, respectively.

For continuous motion transfer machines or production lines, in which finished work is put out continuously and not periodically:

$$t_{uc}=0 \text{ and } t_{lc}=0.$$

If the cycle time does not provide the stipulated rate of production, two or more machine tools are installed at the limiting station.

If an automatic transfer machine consists of automatically-operating independent units or sections and one of them limits the rate of production, this section may be operated at higher speeds and feeds to produce a reserve which will subsequently compensate for the different cycle times of the various sections.

CHAPTER II

AUTOMATED PRODUCTION LINES

§ 120. INOCHKIN PRODUCTION LINE (V.T.P.) FOR MACHINING SEALING MEMBERS

One of the first automated production lines, serving as the starting point for the development of complete automation in the engineering industries, was designed by Inochkin at the Volgograd Tractor Plant.

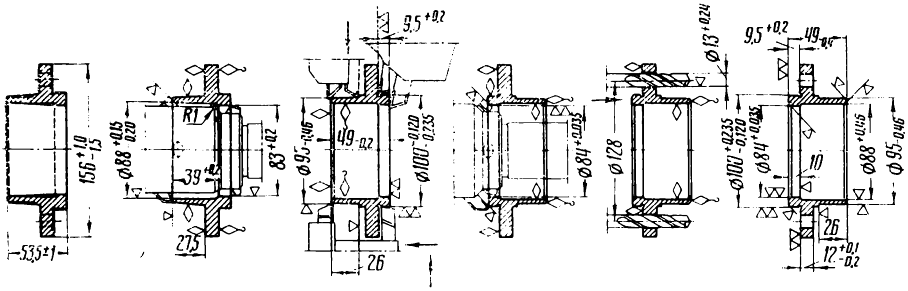


Fig. 212. Tooling layout of the automatic transfer machine for cast iron sealing members.

Inochkin employed machine tools already installed in the plant as the component units. These machine tools were altered as required and equipped with automatic handling and transfer devices.

The tooling layout for a cast iron sealing member, applied to one of the automated lines designed by Inochkin, is shown in Fig. 212.

The line comprises four unit-built machine tools and one altered semi-automatic lathe, model 116 (Fig. 213). All stations (machine

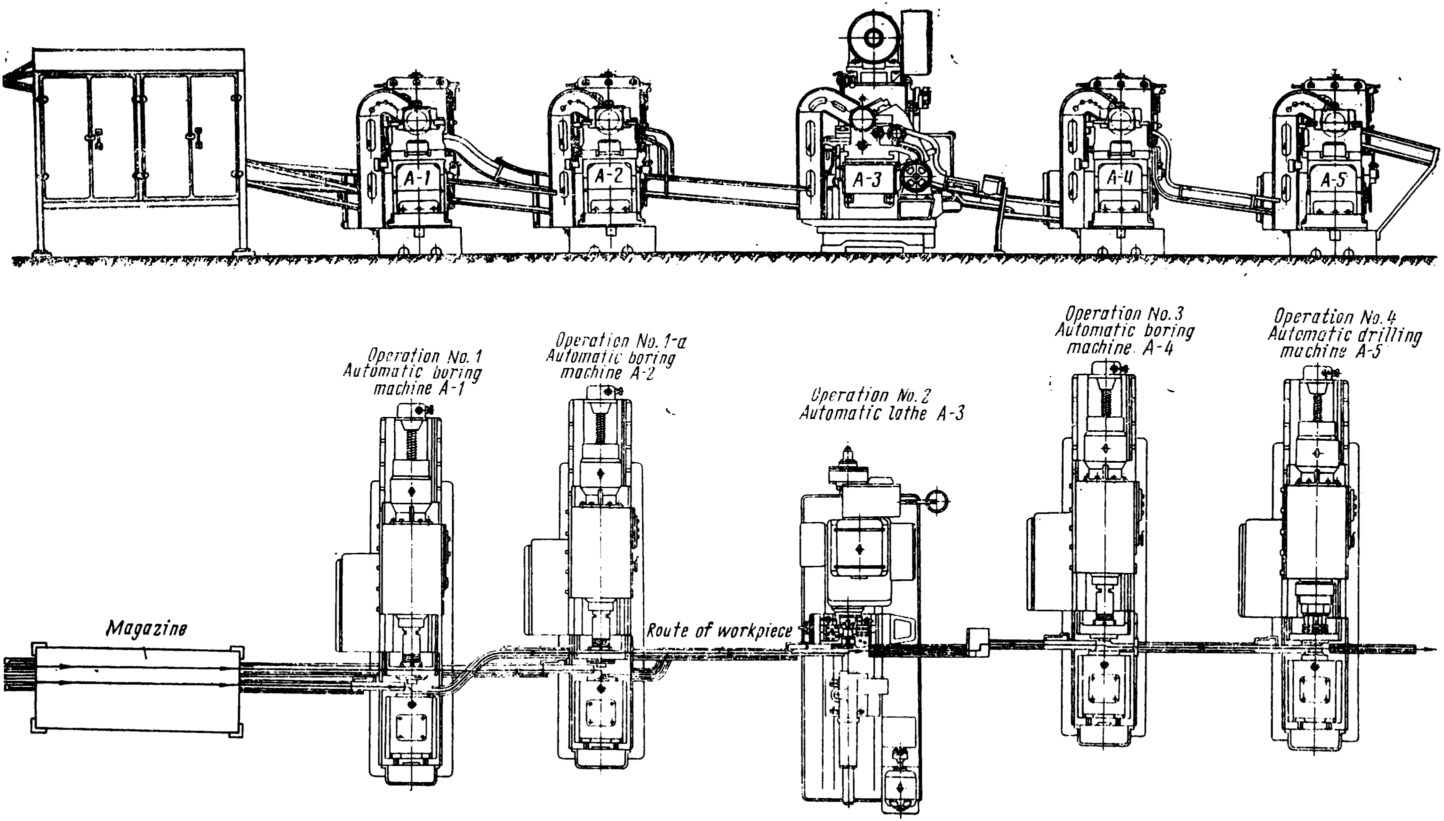


Fig. 213. Machine tool arrangement in automatic transfer machine for cast iron sealing members.

tools) have individual controls. They may operate synchronously or independently of each other. The cycle is started on each machine by the workpiece when it is transferred to the given machine.

Before loading the blank at the beginning of the line, the width of the flange is inspected. The blanks are delivered along two branches of inclined chutes in a divided double flow to the two first boring machines which perform the same operation. In transfer to the third station (multiple-tool lathe), the blanks are mounted on the collet of a hydraulic pusher. Between the third and fourth stations, the workpiece is automatically turned over (through 180°). After this the internal diameters are finish bored and the chambers are made. Four holes are drilled in the flange in the fifth station.

After machining in each station, the workpiece rolls from the receiver to the trough of a vertical indexing elevator, which raises it to the input of the next station.

§ 121. AUTOMATIC TRANSFER MACHINE FOR MOTOR SHAFT PRODUCTION

Fig. 214 *a* illustrates an automatic transfer machine designed for producing the shafts of electric motors and for press-fitting the rotor on the shaft. The shafts are machined between centres on single-spindle hydraulic automatic lathes of frame-type construction. The conveyer for transferring the shafts from station to station is arranged in front; the shafts are delivered to the working position by a transverse pusher. Workpiece transfer is interlocked with the raising and lowering of the shield.

Each machine unit of this line may operate entirely independently or synchronously with the other units. This is an important feature and allows the rest of the machine tools to operate as independent units if one is shut down for any reason.

An automatic lathe of the basic design employed in this transfer machine is shown in Fig. 214 *b*. It has one horizontal and one vertical carriage.

§ 122. AUTOMATIC TRANSFER MACHINE FOR CRANKSHAFT PRODUCTION

Transfer machines for machining such components as crankshafts are much more complex in design. Special devices are required for transferring, clamping, and unclamping the workpiece at the working stations.

One possible design of an automatic transfer machine for turning the journals and cheeks of crankshafts is shown in Fig. 215. All the

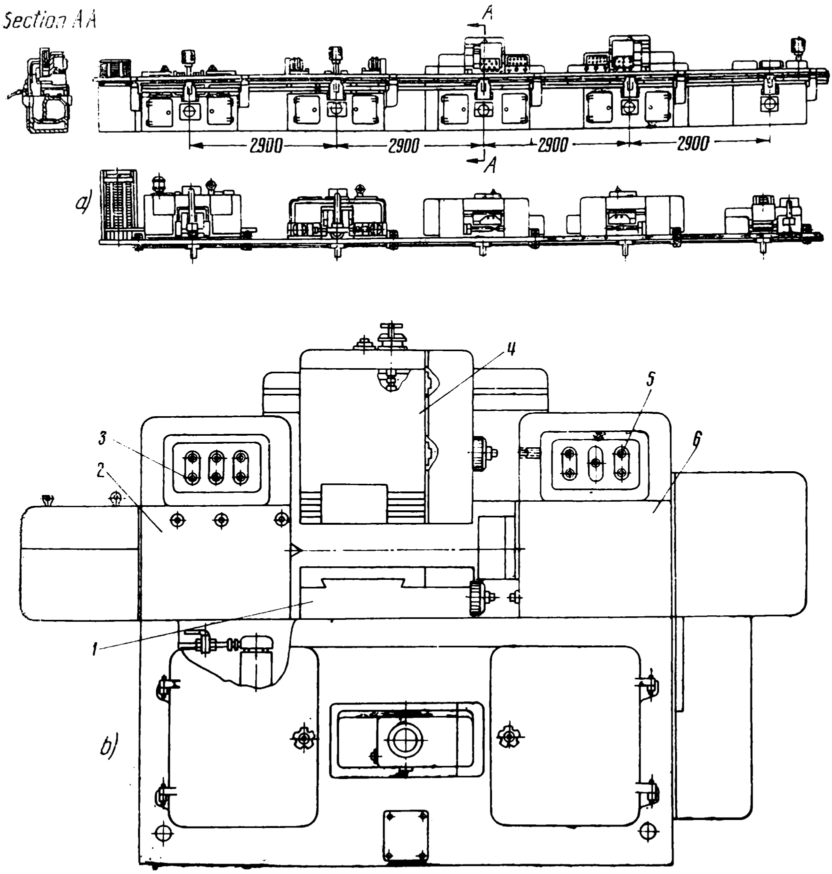


Fig. 214. Automatic transfer machine for motor shaft production.

a—arrangement, *b* — automatic lathe, *1* and *4* — horizontal and vertical carriages, *2* and *6* — tailstock and headstock, *3* and *5* — transfer machine controls.

component machine tools are installed parallel to each other and spaced at equal intervals. The conveyer differs from that of the motor shaft transfer machine (see Fig. 214) in its overhead design (Fig. 215 *a*). This system is more convenient and economical since it saves floor space and facilitates maintenance.

Hydraulic-operation automatic handling devices (Fig. 215 *b*) are arranged on beams above the machine tools. There is one more device than stations. All handling devices travel simultaneously when the machine tools complete their operations.

The automatic handling devices operate with the following cycle of motions (Fig. 215 *d*):

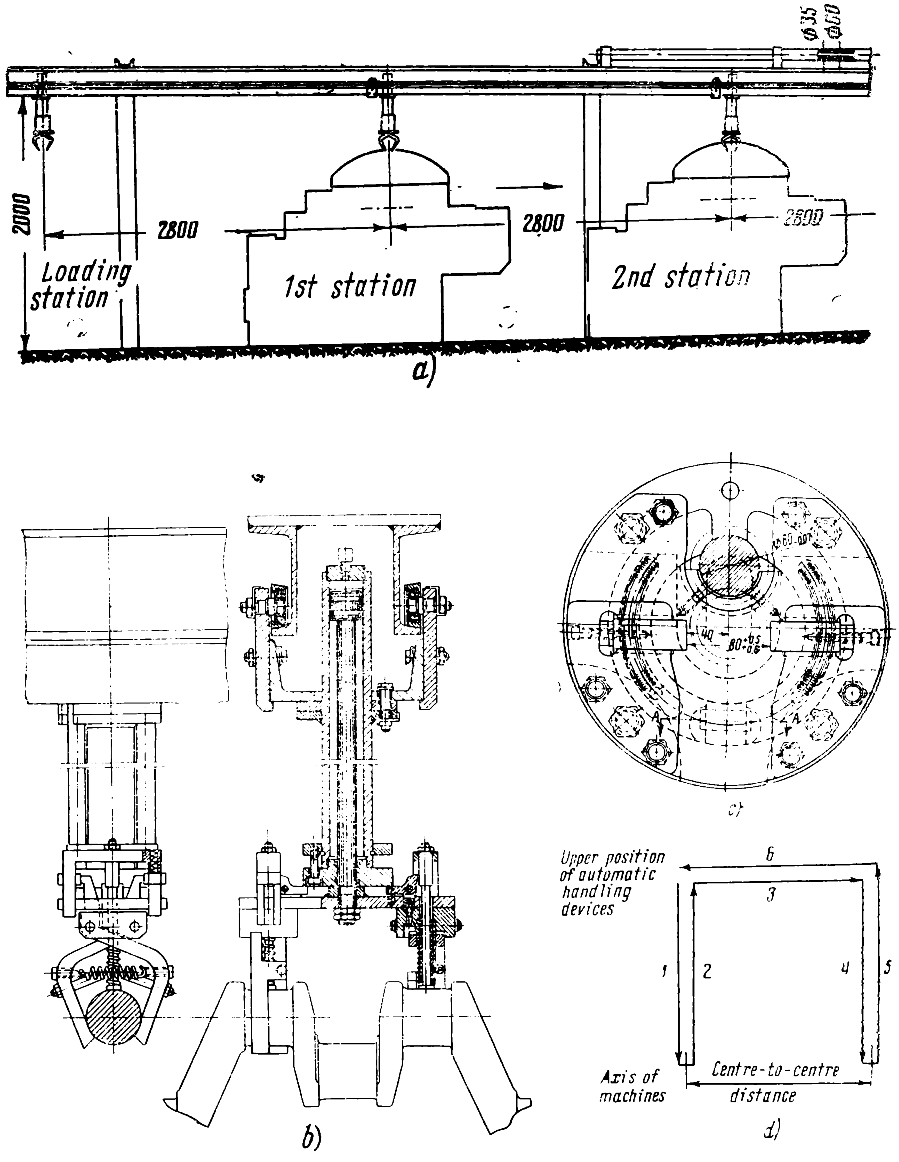


Fig. 215. Automatic transfer machine for crankshaft production.
a—arrangement, *b*—automatic handling device, *c*—chuck, *d*—cycle of handling device movements.

1) all devices move downward, the grips open and grasp the crankshaft by two journals. To enable the crankshaft to be lifted, the clamping fixtures at the stations automatically unclamp and turn so that the loading and unloading slot faces upward (Fig. 215 *c*). The first handling device lowers and grasps the next blank at the loading station;

2) all handling devices move upward;

3) all handling devices travel horizontally (index) through the centre-to-centre distance between the component machines. Thus, the first device will be over the first station, the second, having removed the work from the first station, will be over the second station, etc. The last handling device, having removed the completely machined crankshaft from the last station, transfers it to a position above the unloading station;

4) all handling devices lower and deliver their workpieces to the clamping fixtures;

5) after the crankshafts are clamped at the stations, the handling devices lift upward;

6) all handling devices return horizontally to their initial positions.

This cycle of handling device motion repeats after each machining cycle on the machine tools.

It will be necessary to note, however, that notwithstanding all the advantageous features inherent in transfer machines of the type here described, the idle motions of the handling facilities are quite long and considerably affect the rate of production.

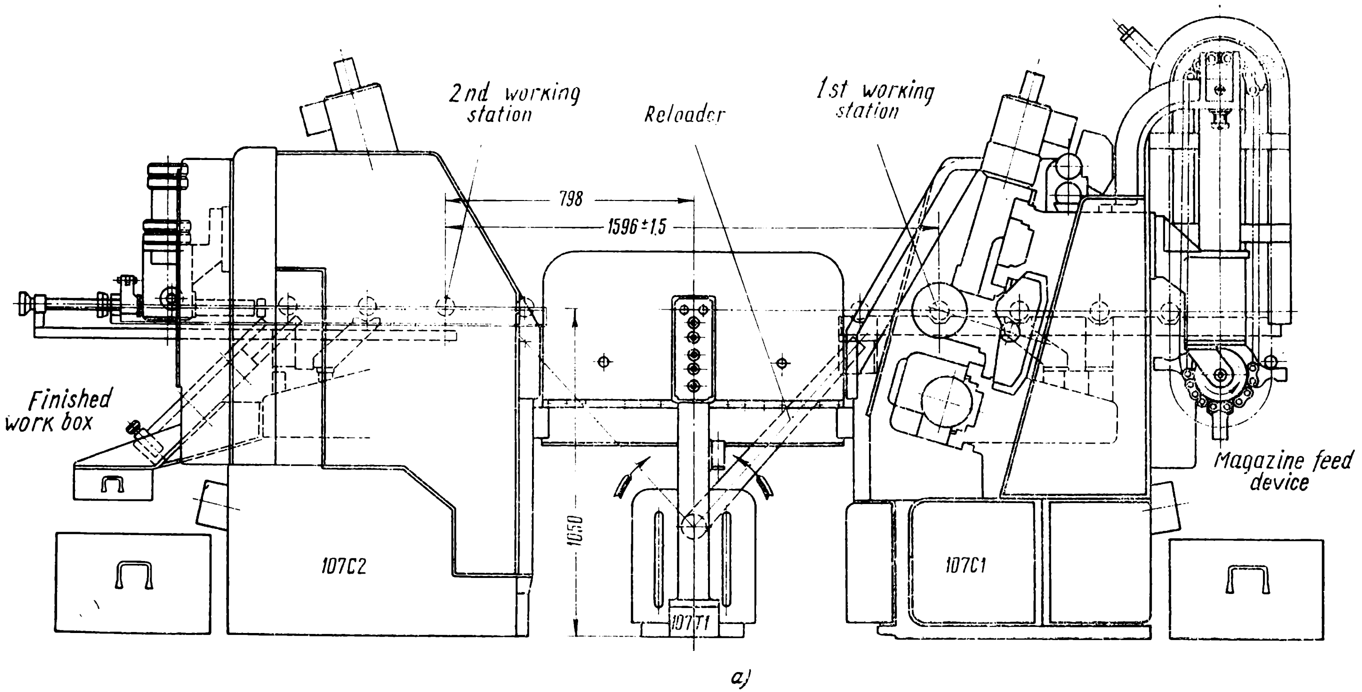
§ 123. AUTOMATIC TRANSFER MACHINE FOR TURNING STEPPED SHAFTS

It is of prime importance to link high-production multiple-tool, tracer-controlled, between-centres, semi-automatic lathes, as well as single- and multiple-spindle automatic bar and chucking machines and finishing lathes into automated lines.

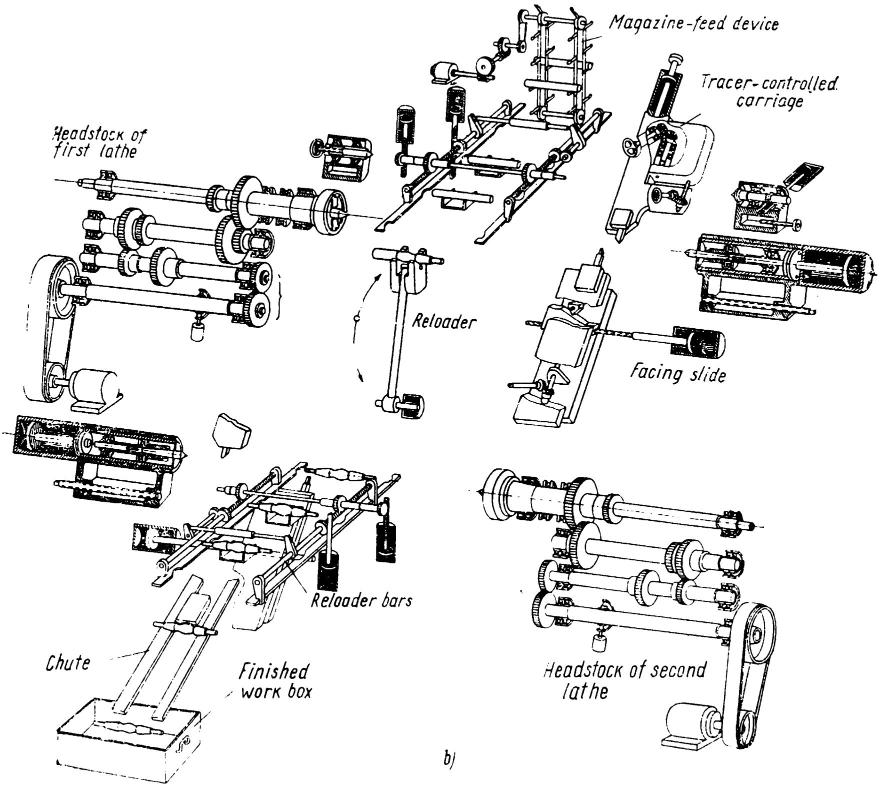
An automatic transfer machine has been made at the Sergo Ordjonikidze Plant for turning shafts. It comprises two single-spindle hydraulic tracer-controlled semi-automatics of standard construction (Fig. 216 *a*).

The machine at the first station (Fig. 216 *b*) is equipped with a magazine-feed device into which a number of blanks are loaded. The magazine-feed operates by hydraulic action. It has two synchronously operating transfer bars which feed the next blank to the working position where it is automatically clamped.

The other end of the shaft is turned at the second station from where the finished shaft slides down a chute into a box.



F i g. 216. Automatic transfer machine comprising two tracer-controlled general-purpose semi-automatics.
a — arrangement.



To Fig. 216: b—isometric view of the transfer machine of Fig. 216a.

§ 124. AUTOMATIC TRANSFER MACHINE FOR STEPPED SHAFTS

This transfer machine consists of five machine tools or stations. At the first station, the end faces of the blank are milled and centred, the two halves of the blank are rough turned separately at the second and third stations and they are finish turned at the fourth and fifth stations.

This transfer machine can be changed over to turn shafts in a diameter range from 25 to 90 mm and in lengths from 350 to 800 mm. The cycle time for a shaft 65 mm in diameter and 610 mm long (blank length—615 mm) is about 1.8 minutes.

The work handling facilities include a chain-type loading unit with a capacity of 24 blanks which periodically feeds the blanks upward to where they are gripped by a hydraulic automatic handling device which transfers them to a suspended intermediate receiver. From here, a second handling device carries the blank horizontally, at the end of each cycle, to the working position.

Such intermediate receivers with a capacity of eight workpieces are provided in front of each automatic lathe and, therefore, the horizontal travel of the handling devices is considerably reduced.

These intermediate receivers also enable one or more machine tools to be stopped for changing or resetting cutting tools, without stopping down the whole transfer machine.

This type of linkage between the machine tools in an automatic transfer machine sharply increases their utilisation factors due to the reduced losses.

CHAPTER III

AUTOMATED PRODUCTION DEPARTMENTS AND PLANTS

§ 125. CONCISE REVIEW

Further developments of automatic transfer machines are automated production departments and plants which represent the highest level of industrial production.

Such departments and plants for the manufacture of precise machine components were fist designed and put into operation in the Soviet Union. Thus, the manufacture of precise items, such as automobile pistons and rings and ball and roller bearings, is accomplished entirely without human participation except to maintain the equipment in the proper working condition. Even inspection operations in these automated establishments are done chiefly by built-in special measuring devices without active control function.

An automated plant for the production of automobile and tractor pistons, designed and built by the Experimental Scientific Research Institute for Metal-Cutting Machine Tools (ENIMS) in conjunction with a number of other institutes and plants, was put into regular operation in 1950. This automated plant has been in operation ever since and its output exceeds that stipulated in the project.

The completely automated production of piston rings began in 1954 in a department designed and developed by ENIMS and a number of machine tool plants.

An automated department for producing antifriction bearings in the First Ball Bearing Plant was equipped, tested, and put into regular operation in 1955.

In addition to other machine tools, all of these automated production facilities were equipped with various types and sizes of automatic lathes. They were designed to enable automatic loading and unloading to be applied, as well as transfer devices.

§ 126. AUTOMATED PLANT FOR PISTON MANUFACTURE

This plant comprises a system of machines, units, conveying and inspection devices joined together to provide a comprehensive automatically-controlled production establishment.

The manufacturing process in this plant begins with the melting of aluminium pigs and includes all operations up to packing the finished pistons, automatically measured and sorted, in sets (Fig. 217).

After loading, the aluminium pigs *1* are melted in the electric furnace *2*. The molten metal is poured into permanent moulds mounted on a multiple-station pouring machine *3*.

A special machine *4* cuts off the gates and the castings are loaded into containers *5* in which they are annealed for 5.5 hours by a stream of hot air from an air heater in the special unit *6*. After heat treatment, the pistons are transferred to the automatic hopper *7*. This is a storage bank which provides a reserve used when the pouring machine is shut down. The containers return to station *8*.

First the locating hole is bored and the skirt end is faced and chamfered (station *9*). Then each piston is automatically mounted on a plate-fixture on which it continues to be conveyed (Fig. 218).

The piston is then machined in an automatic transfer machine consisting of seven machine tools (stations *10* to *15*, incl., and *17*) (see Fig. 217), a machine for weight adjustment *16* and a washing machine *18*.

In the machining department of the plant, pistons are handled by a transfer-bar conveyer *6* on plate-fixtures (Fig. 218).

Upon counterclockwise rotation of the transfer bar *6*, the recessed lugs *7* engage the fixtures with the pistons and transfer them to the next station. After this, the bar rotates clockwise, the lugs disengage the fixtures and then the bar is returned axially to its initial position.

The conveyer is operated and the fixtures with the pistons are located at each station by hydraulic action (Fig. 219). Besides this, the pistons are clamped above by an upper centre. In rotating the pistons in the lathes, the driver is a radial key on the spindle nose which enters a T-slot in the fixture. At the end of their operations, the spindles stop in a position in which the key is in line with and a continuation of the conveyer track.

The lathes in the machining department are four-spindle, vertical, unit-built machines. In each of the two lathes, one for roughing and the other for finishing, turning is performed by two carriages (see Fig. 217, stations *11* and *14*). One carriage has a cross slide for facing the end and for turning grooves; the other feeds longitudinally and turns the outside diameter. The carriages are automatic hydraulic units.

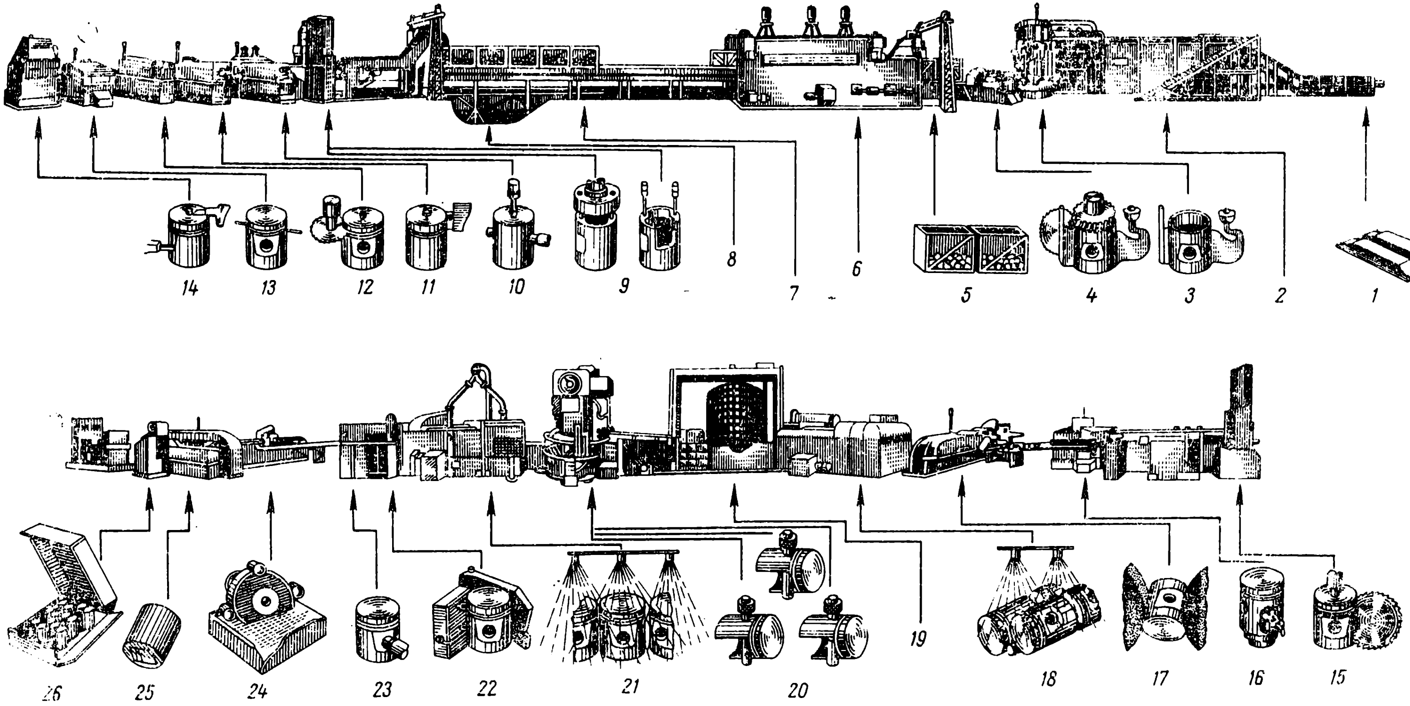


Fig. 217. Automated plant for piston manufacture.

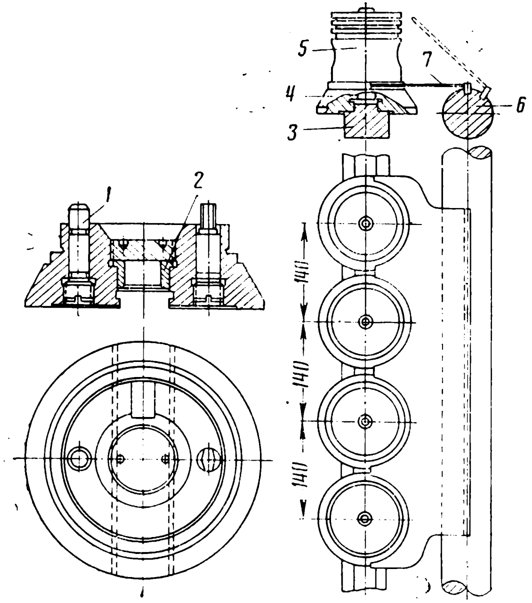


Fig. 218. Piston handling in the machining section of the automatic plant.

1 — **locating pins,** *2* — bushing for locating the plate-fixture, *3*—**guide track,** *4*—**plate-fixture,** *5*—piston, *6*—transfer bar, *7*—transfer bar lug for transferring fixtures with pistons.

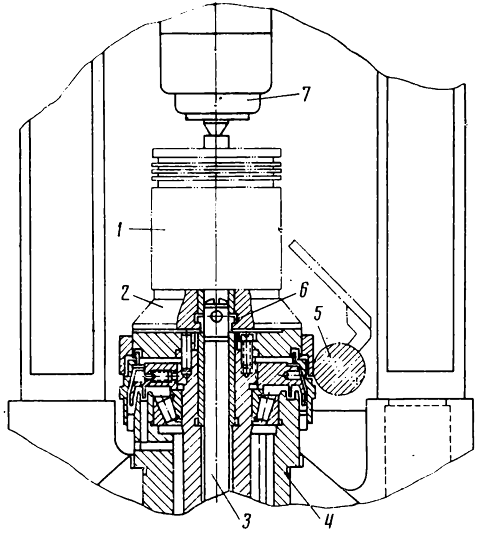


Fig. 219. Mounting and locating of fixtures with pistons on the spindle of an automatic lathe.

1—piston, *2*—plate-fixture, *3*—hydraulic locating pin, *4*—spindle, *5*—conveyer, *6*—driving key, *7*—hydraulic centre.

After passing through the machining operations, the fixtures run on a lift table. Here they are removed from the pistons, lowered to a chain conveyer and returned to the station where the locating surfaces are machined on the piston.

After the washing machine *18* (see Fig. 217), the pistons are transferred to the automatic hopper or storage bank *19* from where they are delivered for boring, reaming and finishing the wrist-pin hole at station *20*. This operation completes the machining and is followed by washing *21*, inspection and sorting *22* and *23*, slushing *24*, wrapping in waxed paper *25*, accumulating the piston size in sets, packing in cardboard cartons (made at this station) and closing the cartons with sealing tape (all at station *26*).

The automated piston plant is manned by only six operators and twelve setup men. The machine tools and other equipment installed in this plant are being continuously improved.

At this plant, the productivity of labour was sharply increased, the cost of the pistons and the production area were substantially reduced. The quality, accuracy, and service life of the pistons produced are much higher than before due to the stability of the manufacturing process.

§ 127. AUTOMATED BEARING MANUFACTURING DEPARTMENT

The lathe section of the automated bearing production department is shown in Fig. 220. Cups and cones (outer and inner rings) of tapered roller bearings are made of forgings delivered through gate *B* to the department and are loaded in bulk, in 250 to 300 piece batches, into the automatic hoppers. The hoppers are designed, not only for storaging the blanks, but also for feeding them out, properly oriented, to the elevators. The rings are then lifted and delivered to the discharge chutes and from there to the branch conveyer. distributor conveyor, and to the machine tools.

The cups and cones are machined in parallel on three eight-spindle automatic lathes in accordance with the tooling layout of Fig. 221. The eight-spindle lathes are of the two-sided type. One of the two upper positions is for loading and the second for transferring or unloading (Fig. 222).

These automatic lathes operate on the following cycle: blank loading at position *1* (left-hand side), consecutive machining in positions *2* and *3*, indexing to position *4* and then transfer to the right-hand side in position *5*. Further, the sequence of movements is the same as for the left-hand side.

After turning the cups on the eight-spindle automatics *1* (see Fig. 220), they are conveyed through the branch chutes, elevator, and overhead conveyer to press *3* where they are marked. From here they are transferred in the same way to the automatic hopper for

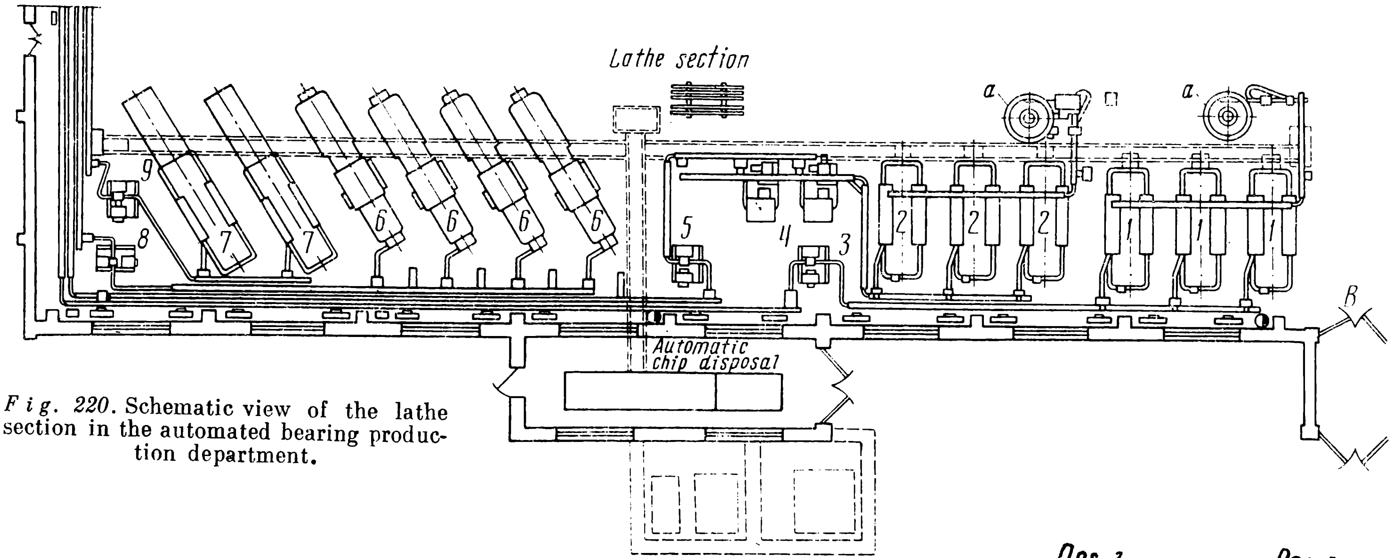


Fig. 220. Schematic view of the lathe section in the automated bearing production department.

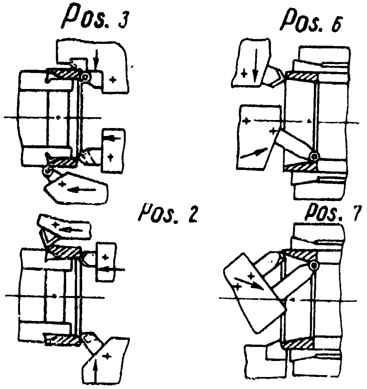


Fig. 221. Tooling layout for turning the cups of tapered roller bearings.

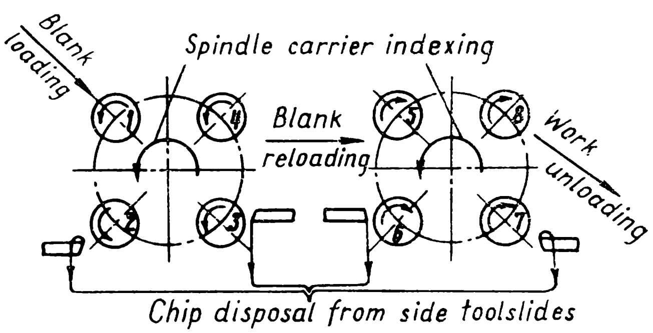


Fig. 222. Principle of operation of the two-sided eight spindle automatic lathes.

1 — loading position, 2 and 3 — working positions, 4 — reloading position, 6 and 7 — working positions, 8 — unloading position.

subsequent processing in the heat treating section of the automated department.

Cones are transferred from machines *2* to single-spindle finishing automatic lathes and further along a parallel route to press *5* and to their automatic hopper.

Bearing rings are made of pipe which is stored on racks *a* from where they are delivered for complete machining. Outer rings pass to one of four two-spindle automatics *6*; inner rings—to one of two six-spindle automatics *7*. Then the rings are marked on presses *8* and *9* and transferred to their automatic hoppers in the heat treating section.

The construction of automatics *6* and *7* differs only slightly from that of general-purpose bar machines. All automatics (1, 2, 4, 6 and 7) use cutting tools tipped with cemented-carbides. They are designed with present adjustment and have a mean dimensional life of four hours. A soap solution cutting fluid under a pressure of 1.5 to 2 atm is used for cooling and washing off chips. Chips are disposed of by a screw conveyer arranged in a special channel under the floor.

Complete or comprehensive automation of production processes one of the main lines of development of Soviet engineering.

Part Five

OPERATION AND MAINTENANCE OF SEMI-AUTOMATIC AND AUTOMATIC LATHES AND TRANSFER MACHINES

CHAPTER I

PREPARING A MACHINE TOOL FOR REGULAR OPERATION

§ 128. SERVICE MANUALS

The most important document concerning the operation and maintenance of any machine tool is the service manual (other names are: operating instructions, operator's handbook, operator's manual, etc.). It contains complete specifications and all information required for efficient operation. The service manual lists data which enable the processing engineer to decide for what size of work and what types of machining the machine tool may be applied. The service manual indicates the spindle speeds, available power, which feeds and speeds may be used, setting-up methods to be used, how change gears are selected, etc. The service manual usually has gearing, hydraulic system, and electrical circuit diagrams, a general view showing the controls, and lubrication and coolant system diagrams. The service manual is primarily intended for the setup man who must be well acquainted with the service manuals of all automatic and semi-automatic lathes attended by him.

Automatic transfer machines are furnished with service manuals for each component machine tool, in addition to all necessary data on the conveying facilities and the general control system.

Data concerning the type, model and manufacture of the machine tool, as well as its photograph and the date and site of installation are listed at the beginning of the service manual.

The section "Specifications" of the service manual indicates the capacity (workpiece size accommodated), working travel of the units, tool clamping facilities, and other dimensional data.

The section "Accessories and Attachments" lists all the standard and special attachments and accessories furnished with each automatic or semi-automatic. The principal devices of this type have been described in the chapters pertaining to the machines on which they are used.

The section "Speeds and Feeds" indicates available power, spindle speeds, and tool feeds, as well as permissible torque, cutting forces, and feed pressures.

Since automatics and semi-automatics are multiple-tool machine tools, service manuals indicate the maximum permissible torque, developed forces and power for simultaneous operation of all the tools.

A control diagram of the model 1A136 automatic screw machine is shown in Fig. 123. The information given here is necessary for operation. Such control diagrams are included in service manuals.

The section "Drive" lists data concerning the drive motors, hydraulic and mechanical elements of the drive, bearings, friction clutches, and other components.

Special columns are provided in the service manual for setting down all alterations in design, made in modernising the machine, and the dates of the general overhauls.

A gearing diagram with a list of all its elements, concerning the main drive, feed drive and auxiliary devices, is an indispensable item in any service manual.

A gearing diagram is essential in understanding all the motions in the machine and is the basis for deriving the setting-up formulas for spindle speeds, tool feeds, and cycle time.

Service manuals for various automatic machine tools may differ in details as do the machines they describe, but almost all service manuals will include the above-mentioned sections.

Main attention is paid in the service manuals of automatic transfer machines to those operation features which ensure the specified workpiece accuracy, cycle time, and trouble-free operation.

§ 129. SHIPPING AND HANDLING

Definite rules for packing, shipping, and handling machine tools must be strictly followed to prevent damages. A new machine tool is received at a plant packed in a box. In unpacking, such indications on the box as which side is to be up and where hoisting ropes are to be applied, must be followed. In no case may a box with a machine tool be rolled over; the inscription "Do not turn over" warns against this.

Special holes or lugs are usually provided on machine tools for rigging the hoisting rope when lifting with a crane hook (Fig. 223). One should always be guided by the handling instructions in lifting a machine. First it is necessary to check whether the hoisting capacity of the crane is sufficient to carry the weight of the machine (indicated on the packing box). *Never stand under a machine, packed or unpacked, when it is suspended from a crane.*

The following rules are important in lifting the machine and rigging the hoisting rope: 1) the hoisted machine should be entirely stable, 2) do not rig the rope over projecting parts of the machine, 3) insert wooden blocks or pads between the rope and the machine,

4) carry the machine to the site of installation on hoisting ropes 60 to 75 mm in diameter, without removing the bottom of the box and the skids.

After unpacking the machine, the anticorrosive slushing compound should be carefully removed with clean aviation gasoline, heavy petrol, or kerosene. Then the surfaces should be wiped dry and coated with a thin layer of machine oil. Metal scrapers or emery paper should in no case be used in cleaning the machine.

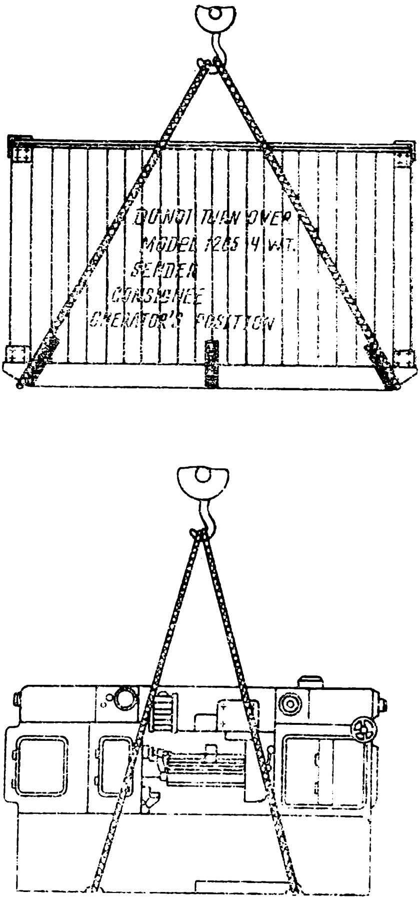


Fig. 223. Handling diagram of the model 1265-4 automatic, with and without the packing box.

§ 130. INSTALLATION

Installation consists in setting the machine tool on its site, levelling, and connection to the power supply. Accuracy in operation may be achieved and retained over a long period of service only if the machine is properly levelled. The machine is placed on a previously prepared foundation (Fig. 224) of a depth depending on the size and weight of the machine.

Installation on a foundation increases the rigidity and vibration-resistance of machine tools, therefore separate foundations are advisable for high-speed machines over 2 or 3 tons in weight. Light-weight automatic lathes may be installed directly on a concrete floor.

Machines are installed in accordance with a layout plan of the given shop or section and a foundation plan which is sent to the buyer before the machine is shipped. Two methods of installing automatic bar machines are illustrated in Fig. 225. Diagonal arrangement of automatics is more frequently employed as it facilitates the attendance of several machines by a single operator. Usually one operator may attend from 5 to 8 single-spindle or from 3 to 4 multiple-spindle automatics. Checkerboard arrangement saves

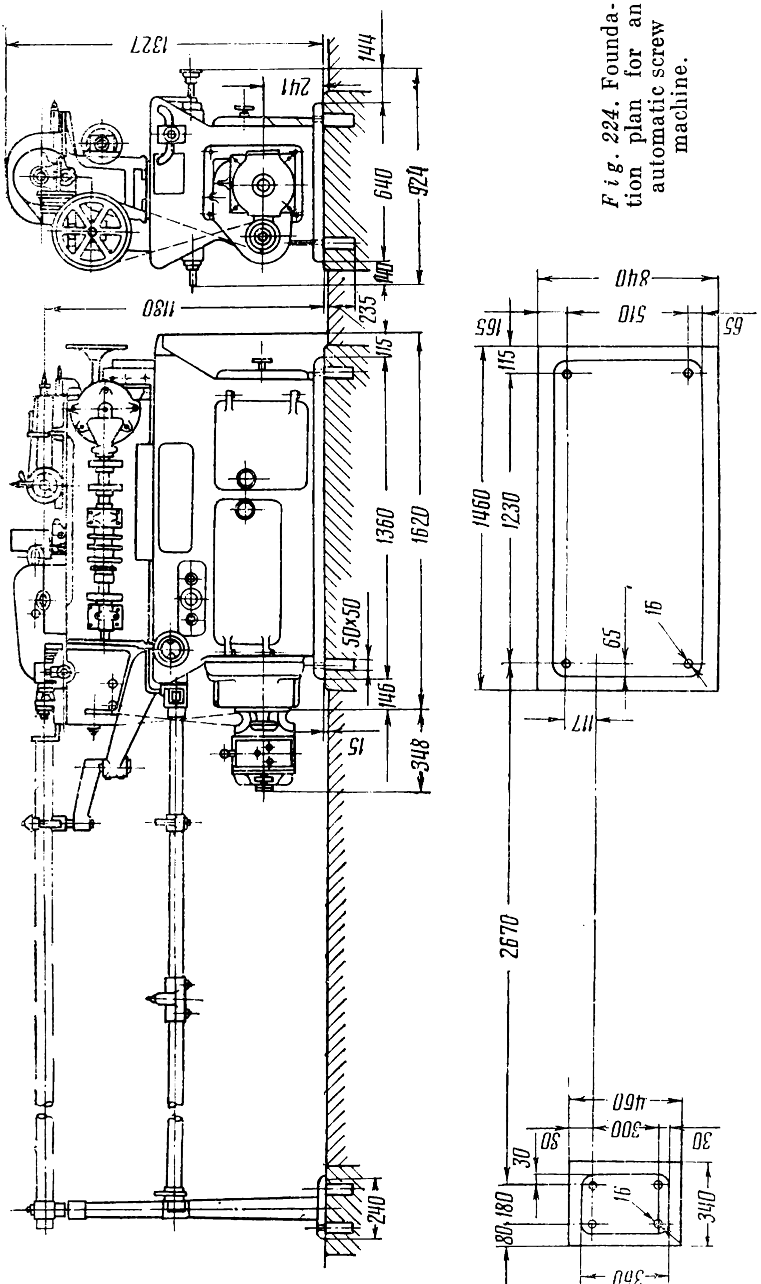


Fig. 224. Foundation plan for an automatic screw machine.

more floor space but is more complicated, both in installation and in maintenance. Semi-automatics are usually arranged to face each other and with a spacing of 500 to 800 mm. This arrangement will enable one operator to attend two or more machines.

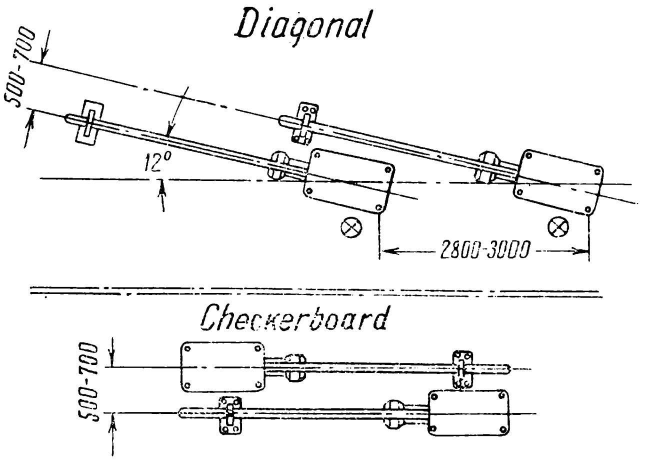


Fig. 225. Arrangements in the shop for single-spindle automatics.

After being set on the foundation (or site), the machine tool is carefully levelled in both the longitudinal and transverse directions. A precise spirit level (accuracy of 0.04 mm per 1 m) is applied on the bed ways for this purpose. Machine tools are levelled by

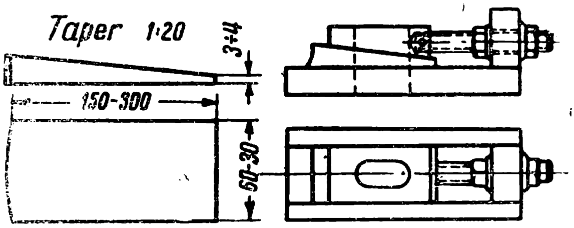


Fig. 226. Wedge and levelling shoe.

means of steel pads, steel wedges, 50 to 60 mm in width and with a 5° or 6° taper, or adjustable levelling shoes (Fig. 226), spaced at 800 to 1,000 mm intervals. The levelling continues by driving in the wedges or adjusting the shoes until the ways of the main components of the machine are precisely horizontal or vertical, as required. After levelling, the base and foundation bolts are grouted with cement mortar. The foundation bolts are drawn up firmly only after the grouting has properly set. The nuts of the foundation bolts should be tightened uniformly, i. e., gradually one after another, checking the position of the machine all the time with the level.

In the installation of automatic transfer machines, special attention should de paid to the alignment of the component machines, proper assembly of the conveying and handling devices, and precise levelling of the locating surfaces.

During installation, drive motors are connected to the power supply mains in accordance with the electrical circuit diagram. This connection is checked by noting the direction of motor rotation. Then the machine is lubricated and the tanks and reservoirs are filled with cutting fluid and lubricant.

An automatic or semi-automatic lathe is tested by an idle run. During this run, all mechanisms should operate properly, without noise, knocks, jerking, or vibration. Plain bearings should not heat to a temperature over 60° C and antifriction bearings over 75° C. Most up-to-date automatics and semi-automatics can operate, not only on an automatic cycle, but also on a setting-up cycle. This enables the setup to be comprehensively checked, as well as the size of the workpiece, by engaging the separate units of the machine consecutively one by one.

Setting-up operation is provided not only for the separate components of an automatic transfer machine but for the system as a whole.

Automatic machine tools or transfer machines may be put into regular operation only after being tested and checked in the setting-up cycle.

§ 131. LUBRICATION

Proper lubrication ensures not only trouble-free operation and a prolonged service life of a machine tool, but accuracy of performance as well. Consequently, lubrication is of vital importance.

Lubricant is delivered to the friction surfaces of a machine during operation to prevent direct contact of these surfaces and thus to reduce friction and wear and to facilitate relative motion of mating parts.

In automatic machine tools and transfer machines, lubricant must be delivered automatically to all points of lubrication before starting operation.

Various systems of lubrication are employed on automatic and semi-automatic lathes. As a rule, the more important points are lubricated independently of the general system. In the latest models, oil is fed under pressure from a lubricator to these points. Important points of lubrication include the spindle bearings, carriage and slide ways, and camshaft bearings. Gears are usually lubricated by a splash or spray method; worm gearing by arranging the worm in an oil bath. Oil may also be fed by gravity from a reservoir arranged above the points it accommodates. Less important points or points with poor accessibility are lubricated by hand pump or by standard oilers with hinged cups.

A lubrication system may include a pump which delivers filtered oil to distributors, lubricators, or oil baths.

Mineral oils, such as Machine oil L or Spindle oil Z (U.S.S.R. Std. GOST 1707-51), are recommended for lubricating automatic and semi-automatic lathes. In selecting a grade of lubricant, it is necessary to take into consideration the speed and pressure between the moving parts to be lubricated.

All reservoirs should be washed and the whole lubricating system blown through each 1.5 or 2 months of operation. In addition, the filters should be cleaned and clean lubricant should be added to the system periodically.

If an automatic machine tool or transfer machine is restarted after standing idle for a period of time or after repairs, several minutes will pass after starting the machine before the piping will be filled with lubricant.

As a rule, the service manual of each automatic or semi-automatic includes a lubricating diagram and a chart of instructions which lists the points of lubrication and the amount and grade of lubricant required for each point.

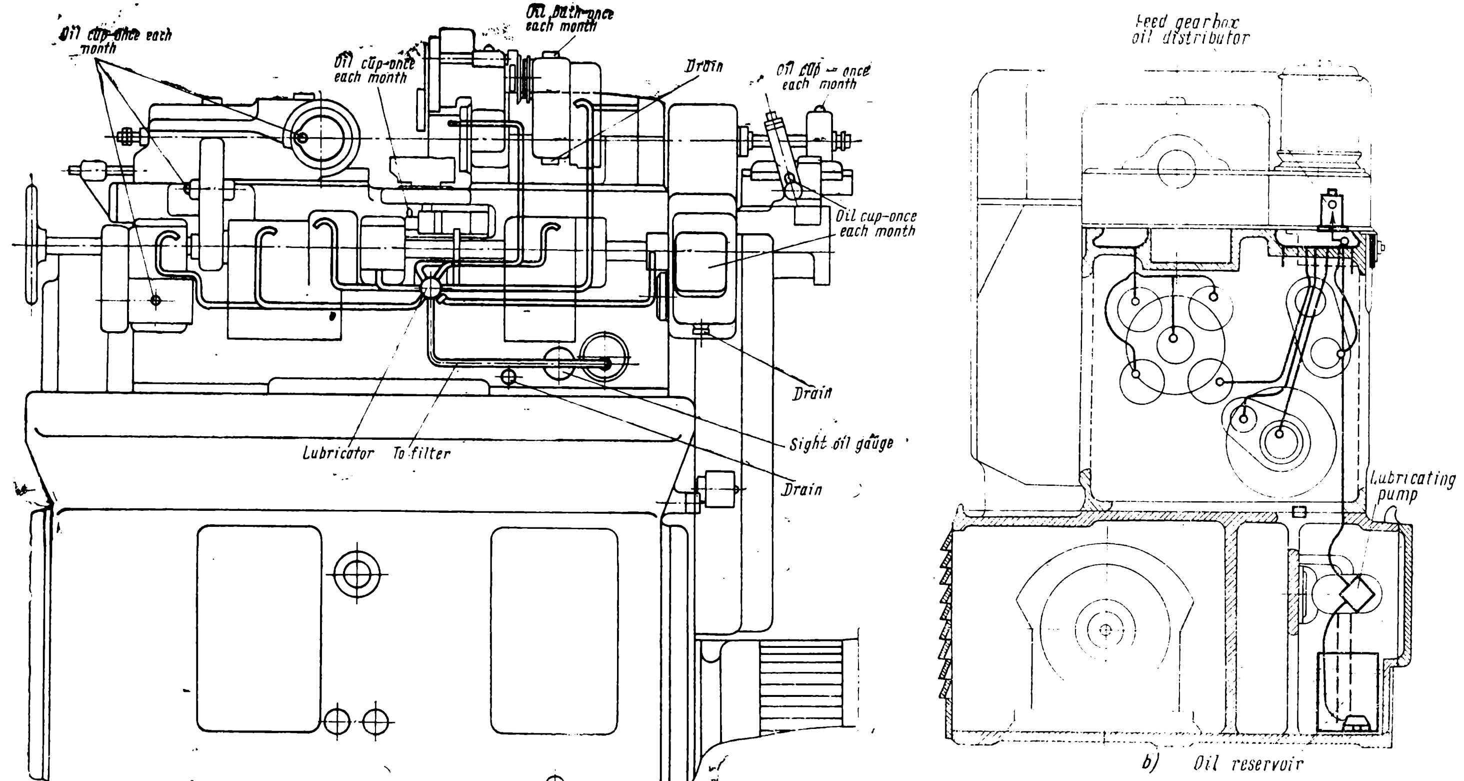
Sections of lubricating diagrams for automatic lathes are illustrated in Fig. 227.

§ 132. COOLING THE CUTTING TOOLS

Cooling is a vital factor in machining metals. It enables higher cutting speeds and feeds to be applied, increases tool life, and enables more accurate and finer surfaces to be obtained.

A properly designed and maintained coolant system increases the rate of production and improves the quality of work being produced.

A centralised coolant system, delivering cutting fluid (also called coolant) to all positions and tools simultaneously, is usually used in automatic machine tools. Mineral oil is most often used as a cutting fluid; sulphurised cutting oils are more seldom employed. Sulphurised cutting oils or soluble oil cutting fluids may be used only when there is no danger, whatsoever, of them getting into the lubricating system. A large number of automatic lathes use mineral oils. Sulphurised cutting oils, containing up to 2 per cent sulphur, may give satisfactory results in thread-cutting.



a)

b)

Fig. 227. Lubricating diagrams.

a — automatic screw machine, model 1A136, *b* — four-spindle automatic bar machine, model 1240-6.

The cutting fluid reservoir is usually a specially-provided compartment in the base or leg of the machine. Sills, provided in the bottom of the reservoir, facilitate settling of the cutting fluid. *The cutting fluid must pass through a filter before delivery to the tools.*

The pressure in the system should be sufficient to direct a stream of fluid to the working zones of the tools. There is often a separate nozzle for each toolslide of multiple-slide machines. Cutting fluid is delivered to turret tools through a central pipe. The pipelines have articulated joints or flexible tubes to enable the nozzle to be set at any required position.

A device for regulating cutting fluid feed and for shutting it off in setting up must be provided in the coolant system.

Cutting fluid must never be allowed to enter the lubricating system since this dilution will deteriorate the lubricant quality and may result in bearing seizure and jamming in the ways.

The coolant system must be washed out from time to time to remove fine chips; the cutting fluid is drained for this purpose. The system should be periodically replenished with fresh cutting fluid.

When a large number of automatic and semi-automatic lathes are installed in a plant, cutting fluid is usually cleaned and renovated in a centralised system. In automatic transfer machines, the coolant system is usually centralised in the same manner as used-fluid drainage and its filtering.

Coolant systems of single- and multiple-spindle automatics are illustrated in Fig. 228.

It must be noted that no oil or other inflammable cutting fluids may be used at extremely high cutting speeds.

§ 133. CHIP DISPOSAL

One of the most important problems in machine tool operation is chip disposal. The chip must not remain in the working zone of automatic machine tools since the operator is not in attendance continuously during operation. Poor chip disposal will worsen cutting conditions and may be the cause of tool breakage. Thus it may lead to a decrease in the production rate and to the production of low-quality work.

The application of high-speed metal cutting considerably increases the amount of chips removed in a unit of time. For this reason, unsatisfactory chip disposal in automatic lathes will result in frequent shut-downs.

To provide proper chip disposal, it will be necessary, in the first place, to have the cutting tools designed to break up the chip (Fig. 229). Chips, broken into small pieces, occupy less space. They

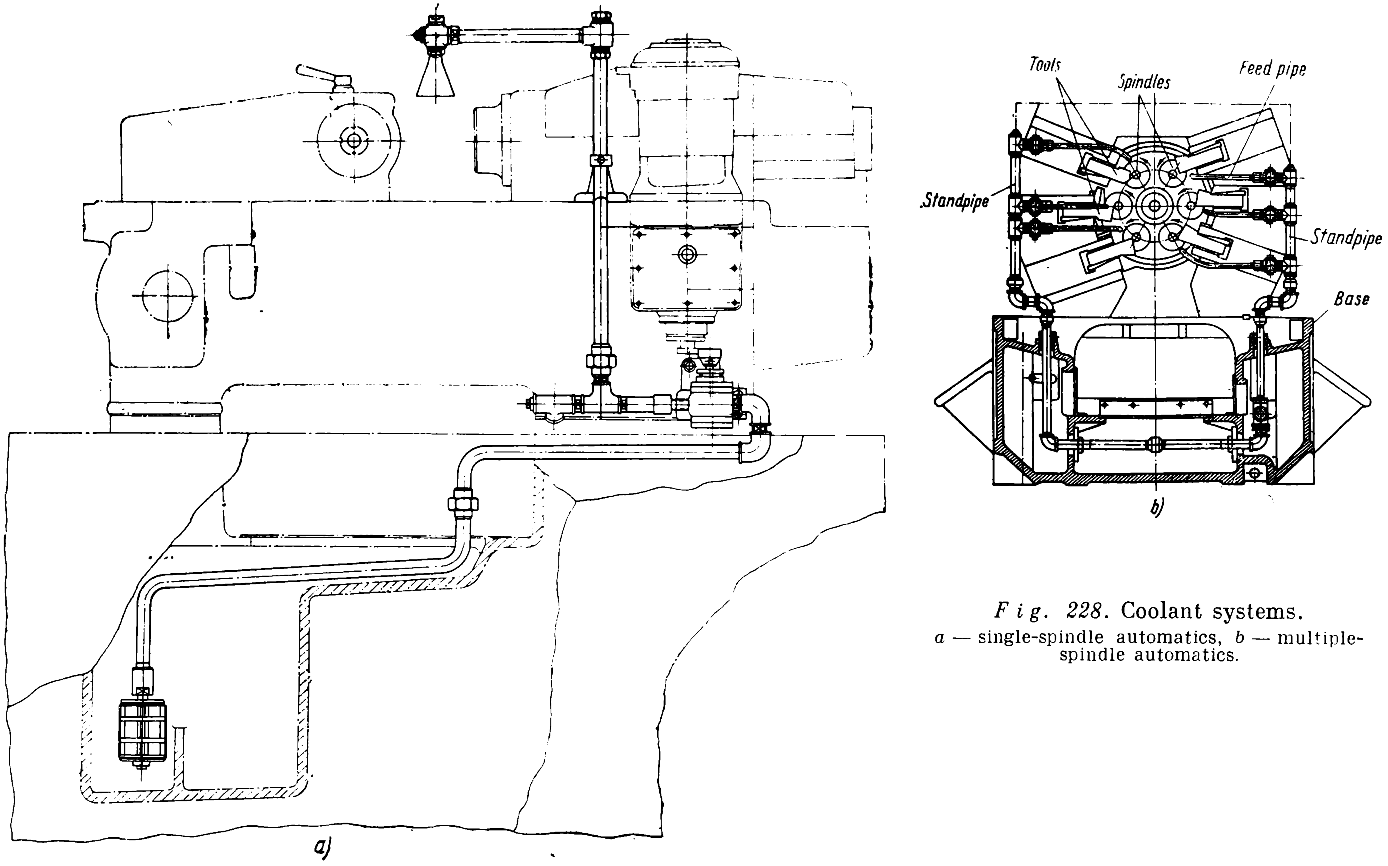


Fig. 228. Coolant systems.

a — single-spindle automatics, *b* — multiple-spindle automatics.

do not remain on the tool or work and are more easily disposed of in the working zone. A vibration method has been recently applied to break up chips in turning. It makes use of vibratory movement of the cutting tool and is known as the kinematic method (Fig. 230). In turning and drilling, periodic disengagement, such as variation of the tool or drill feed, will very satisfactorily break up continuous chips.

Power-operated chip conveyers are used for chip disposal in the latest Soviet designs of automatics and semi-automatics. Two types of chip conveyers for multiple-spindle automatics are illustrated in Fig. 231. The scraper conveyer (Fig. 231 *a*) is inclined and consists of sheet metal scrapers or flights attached to roller chains driven by two pairs of sprockets. Chips fall on the conveyer belt and are delivered to a special box.

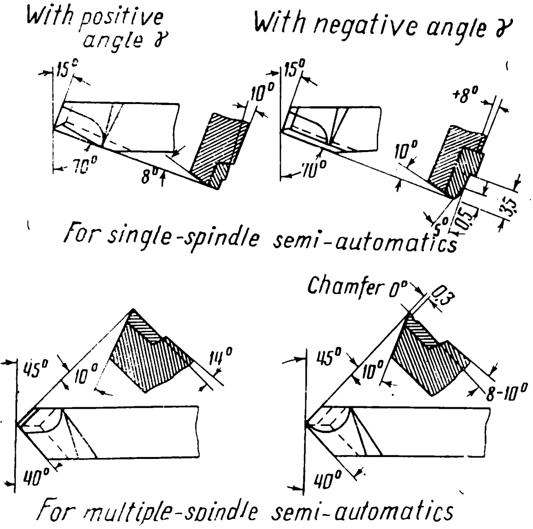


Fig. 229. Tool angles of straight turning tools, tipped with cemented carbide and having chip breaker grooves.

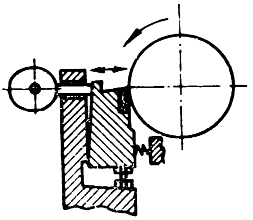


Fig. 230. Kinematic (vibratory) method of breaking up continuous chips.

The screw type chip conveyer (Fig. 231 *b*) is more reliable in operation. It quickly removes the chips and is not so sensitive to jamming and choking.

There is always a danger in making small workpieces of their getting into the chips and being lost. The use of work catchers is required for such cases. These consist of a chute which is lifted at the moment when the finished workpiece is cut off. The workpiece drops on the chute and slides down to the box for finished pieces. Then the chute lowers again to free the space in the bed for falling chips.

A single general chip conveyer usually serves all the units of a transfer machine.

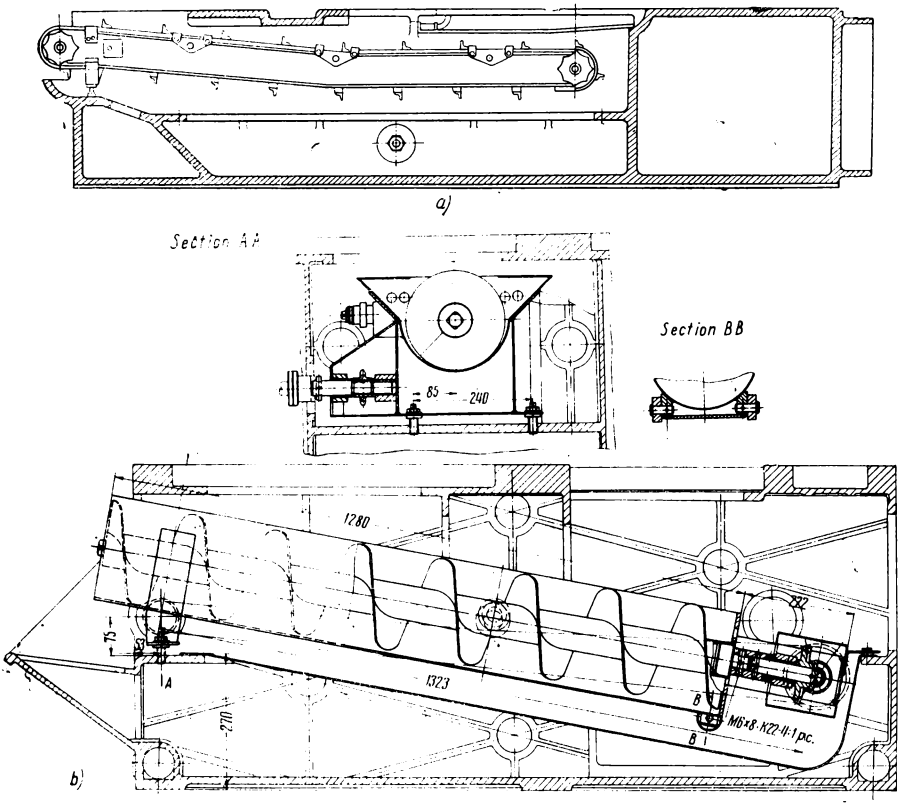


Fig. 231. Chip conveyers.
a—scraper type, *b*—screw type.

§ 134. LOCAL LIGHTING

The most favourable lighting conditions must be provided for efficient machine tool handling.

Natural illumination, through windows and skylights, is usually sufficient in the daytime.

Artificial lighting must provide for setting the lamp to any convenient position. All work lamps must be equipped with shades or reflectors that protect the operator's eyes against direct light. Two zones must be distinguished in the lighting of machine tools: one is the machine control and work loading zone and the other is the working and work inspection zone.

The control and loading zone may be illuminated by the shop system while the working zone requires local lighting of an intensity which enables the machined surface and the cutting tools to be easily discerned without any eyesight strain whatsoever.

§ 135. GUARDS, PROTECTING DEVICES, AND SAFETY MEASURES

Systematic instruction of automatic lathe operators on servicing and maintenance is one of the everyday duties of the setup man.

The setup man should teach the operators up-to-date working methods and proper workplace arrangement.

Higher quality work and increased ratio of production depend to a large extent on the setup man. *Another important duty of the setup man is to acquaint the operators with the use of all guards and with accepted safety measures.*

Automatic and semi-automatic lathes are multiple-tool machines in which a large number of driven elements move at high speeds.

Guards are provided on these machines to protect the operator against flying chips and splashing coolant and also to exclude the possibility of the operator clothes, hair, or hands being caught by the rapidly moving components.

Guards are designed to reliably protect the operator and to be easily removed during servicing. They should not hinder the operator in the manual operations required for machine control and should allow him to watch the operation of the machine and the condition of the tools.

The following rules, usually included in operating inctructions, must be followed in using guards:

1) before starting the machine, install all guards and check their fastenings; in setting up, the guards should not be removed before stopping the machine;

2) never touch drive elements or moving components, enclosed by guards, during operation;

3) after stopping the machine, switch off the power supply before removing the guards;

4) during operation or setting up, eliminate the possibility of chance persons starting the machine (this is of special importance for machines with dual controls).

In semi-automatic lathes the working zone is usually enclosed by light metal splash guards or shields with transparent windows. These devices must be lifted or shifted to the side each time work is loaded and unloaded. During operation, however, they should completely enclose the working zone.

The splash and chip shields shown in Fig. 232 are used on single- and multiple-spindle automatics.

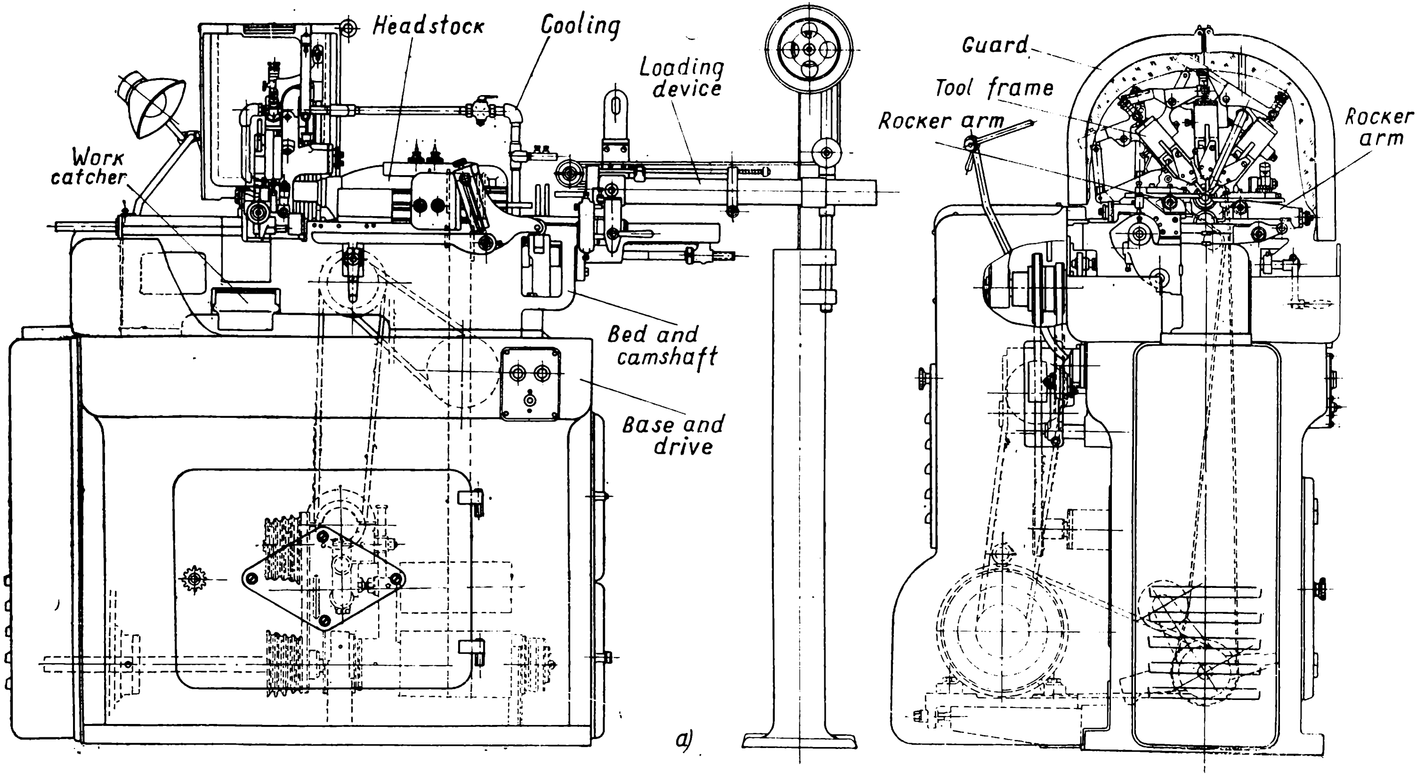
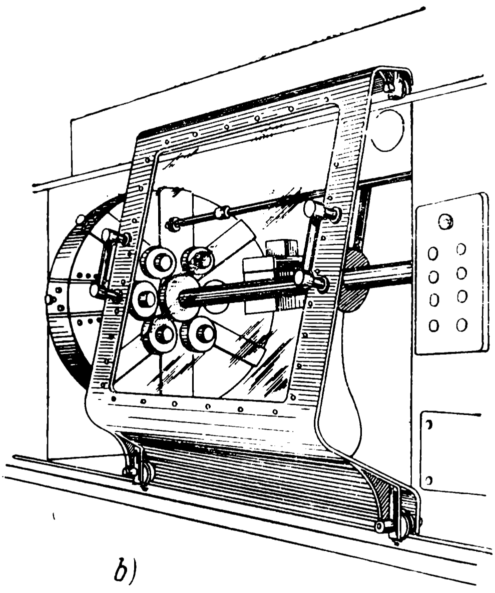


Fig. 232. Guards.
a—for Swiss-type automatic screw machines,



To Fig. 232.
b — for multiple-spindle automatics.

Reliable protection must be provided on the rotating bars of bar-type automatics so that no space is left between the stock reel tubes and the stock feeding mechanism where loose ends of clothes or caps may be caught up.

The interlocking arrangement in semi-automatic lathes, which does not allow the machine to be started or spindle rotation engaged if the work is improperly clamped, must be kept in a working condition.

A measure for operator safety, provided on all new Soviet automatics, prevents the machine from being started until all loose handles, levers and handwheels are taken off. In earlier models, such items could be thrown off at a high speed and with a large force when the machine was started.

Special care must be taken to prevent the automatic cycle from being switched on during setting up or tool resetting.

Soviet automatics and semi-automatics all have individual motor drives which should be serviced with all necessary electrical precautions.

Current-carrying components should always be reliably guarded to prevent contact with operators. *It is absolutely necessary to ground all motor frames, starters and adjacent metal parts, as well as the whole machine by means of the grounding bolt which is indicated on the machine by an index plate.*

Electric starting devices should be conveniently located and protected against accidental engagement. In push button stations, the start button should be sunk 3 to 5 mm below the face to prevent it from being pushed accidentally. Stop buttons should be of a red colour and should operate absolutely without fail from the slightest contact.

Besides the above-mentioned, there are also general safety rules which fall into three groups: rules which must be observed before starting the machine, during operation, and after stopping the machine.

1. *Safety rules which must be observed before starting the machine.*

The following should be brought into order:

a) clothes and hair (unbuttoned, flapping clothes must not be worn, sleeves should be tightly buttoned or tied at the wrist);

b) the operator's position or workplace (there should be nothing that the operator may slip on or trip over).

Check the following:

c) have all guards been replaced; do the clamping and locking devices operate properly?

d) have all loose levers and handwheels been removed?

e) do the coolant and lubricating systems operate properly?

f) do all chip disposal devices operate properly, have wire hooks been prepared for pulling out chips?

g) are all belts and chains properly tensioned?

h) has the automatic been tested for a few minutes on an idle run?

2. *Safety rules which must be observed during operation*:

a) never remove guards and shields;

b) never break up chips with bare hands, push them on with wire hooks;

c) never stop the spindle with the hands if it still rotates after being disengaged;

d) never put blanks, finished work, tools, or waste on the machine;

e) never use worn or sprung wrenches which may slip off nuts or bolt heads during clamping or unclamping;

f) never lubricate, wipe off, or clean the machine during operation;

g) never remove or replace tools, load or unload work when the spindle or other unit is rotating;

h) never check or measure the workpiece while it is in rotation;

i) never remove or replace belts, gears, or chains without stopping the machine.

It will be necessary to:

j) properly restock automatics; clamp work in semi-automatics correctly and reliably;

k) keep the workplace clean (never encumber it with parts over which the operator may trip and fall);

l) keep the hands as dry as possible.

3. *Safety rules which must be observed after stopping the machine*:

a) switch off the motor, even during the shortest stops;

b) remove the workpiece;

c) check whether the bar stock is of sufficient length in automatics;

d) wipe off the machine and coat it with a thin layer of oil, remove all chips caught in the working zone.

Much attention is paid to operator safety in the Soviet Union, *therefore the operation of machine tools is absolutely safe if all safety rules are strictly observed.*

CHAPTER II

TESTING MACHINE TOOLS

§ 136. TESTING AUTOMATIC AND SEMI-AUTOMATIC LATHES

Tests are conducted to check the accuracy and performance of machine tools, newly manufactured or after repairs. Such tests may be carried out only after properly levelling the machines and after an idle test run for a period of 2 or 3 hours.

The principal requirements, stipulated for automatic and semi-automatic lathes, are based on their capacity for producing work of the specified accuracy and surface finish at the specified rate. The tests, therefore, must be such as to establish the quality of the machines.

Automatics and semi-automatics are subject to the following production (acceptance) tests:

1) idle run test, checking the quality of manufacture and the operation of all mechanisms in the electric, hydraulic, and pneumatic equipment and in the lubricating and coolant systems, and also checking the capacities of the machine;

2) accuracy tests;

3) performance tests and determination of the rate of production;

4) workpiece tests (checking the surface finish and accuracy of machined workpieces).

In the U.S.S.R. production tests must conform with the general specifications established for the manufacture and acceptance of metal-cutting machine tools (U.S.S.R. Std. GOST 7599-55).

Idle run tests are conducted at different spindle speeds and toolslide feeds but, in all cases, without loads. In addition to this, all the mechanisms are switched on or engaged, the actual spindle speeds are measured, as well as the travel of all units (minimum and maximum) to check whether the characteristics of the machine conform to the specifications. An idle run test determines whether mechanisms are in a proper condition and operate correctly when they run without loads. This tests the proper action of all control devices in engaging, changing over, and transmitting motions, the action of interlocking devices, reliability of locking facilities and a complete absence of accidental engagements, misalignments, and jamming. Hydraulic-action automatics and semi-automatics should operate at all speeds and feeds of the hydraulic drive without impacts or vibration.

Idle run tests also include the measurement of consumed power at different spindle speeds. These measurements are usually made with a wattmeter or by using a *voltmeter* and *two ammeters* (for separate voltage and current measurements).

Spindle speeds are measured by a *tachometer* or by a *revolution counter*, in conjunction with a *stop watch*. In the second case, the actual number of revolutions is noted on the counter for a definite period of time measured by the stop watch.

The actual rate of feed of the toolslides is measured by counting off 100 spindle revolutions with the revolution counter and measuring the corresponding toolslide travel with a steel rule. The measured travel divided by 100 will be the feed per revolution.

The feed of hydraulically-operated units is determined by measuring the travel in 30 or 60 seconds (using the stop watch). From this, the rate of feed in mm per minute may easily be computed.

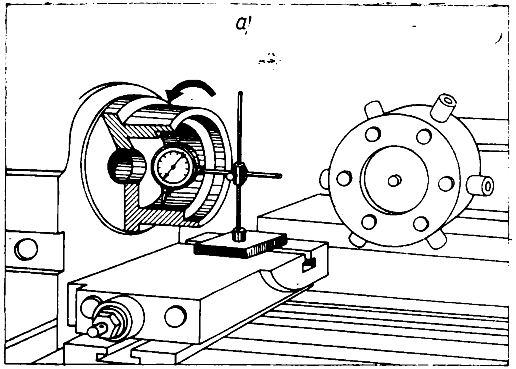
Accuracy tests of automatic lathes are conducted with manual traverse of the units (with the power supply switched off). These tests consist in checking the relative position of the principal parts and units, such as beds, columns, tables, carriages, toolslides, spindles, etc. The aim of accuracy tests is to determine the actual errors concerning straightness, flatness, out-of-roundness, parallelism, squareness, true running, etc.

Each of these errors should not exceed the permissible values stipulated in the accuracy standards for the given type and size of machine.

The essence of the accuracy tests and the methods employed are best explained in an example of an automatic screw machine. This machine (Fig. 233) has ways for turret slide travel. These ways must be straight in both horizontal and vertical planes and parallel with the axis of rotation of the spindle. Otherwise, the tool nose, in turning, will not travel along a straight line parallel with the axis of the machine and work of true cylindrical form cannot be turned. Flatness of the ways in a horizontal or vertical plane (if the machine has been properly levelled previously) can be checked with an ordinary or frame-type spirit level, reading to 0.02 or 0.04 mm per metre (Fig. 234 *a*). The level is moved along the tested surface. Straightness may be tested by a precise straight-edge applied on two gauge blocks of equal height. The distance under the straight-edge to the ways is measured at various places by a set of gauge blocks and a thickness gauge.

This method is used to determine the staightness errors in ways. If, for example, at various points under the straight-edge, thickness gauges of 0.10 mm, 0.05 mm, and 0.08 mm will pass and the distance between the blocks supporting the straight-edge equals one metre, then the maximum error per metre will be 0.10—0.05 = = 0.05 mm.

It is evident that if thickness gauges of the same size pass under the straight-edge, all along its length, the way will be as straight as the straight-edge. Therefore, the maximum error in straightness will be the difference between the maximum and minimum size of thickness gauge passing between the straight-edge and the way.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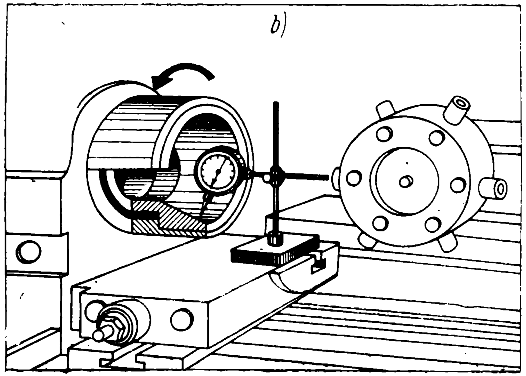
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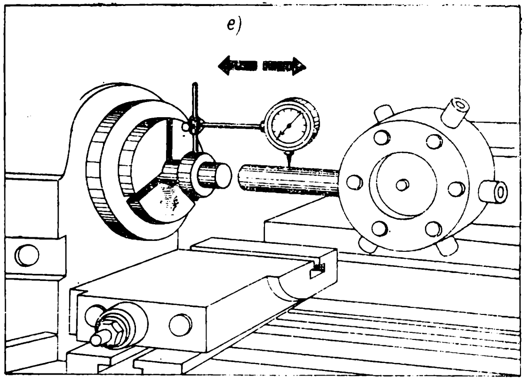
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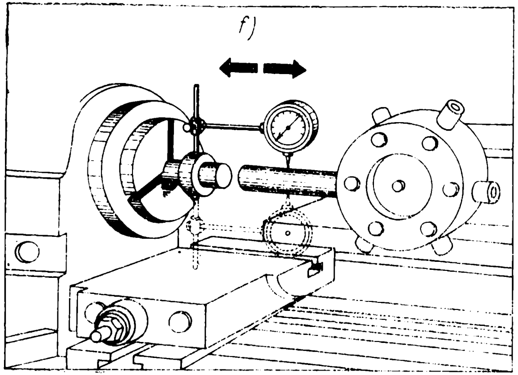
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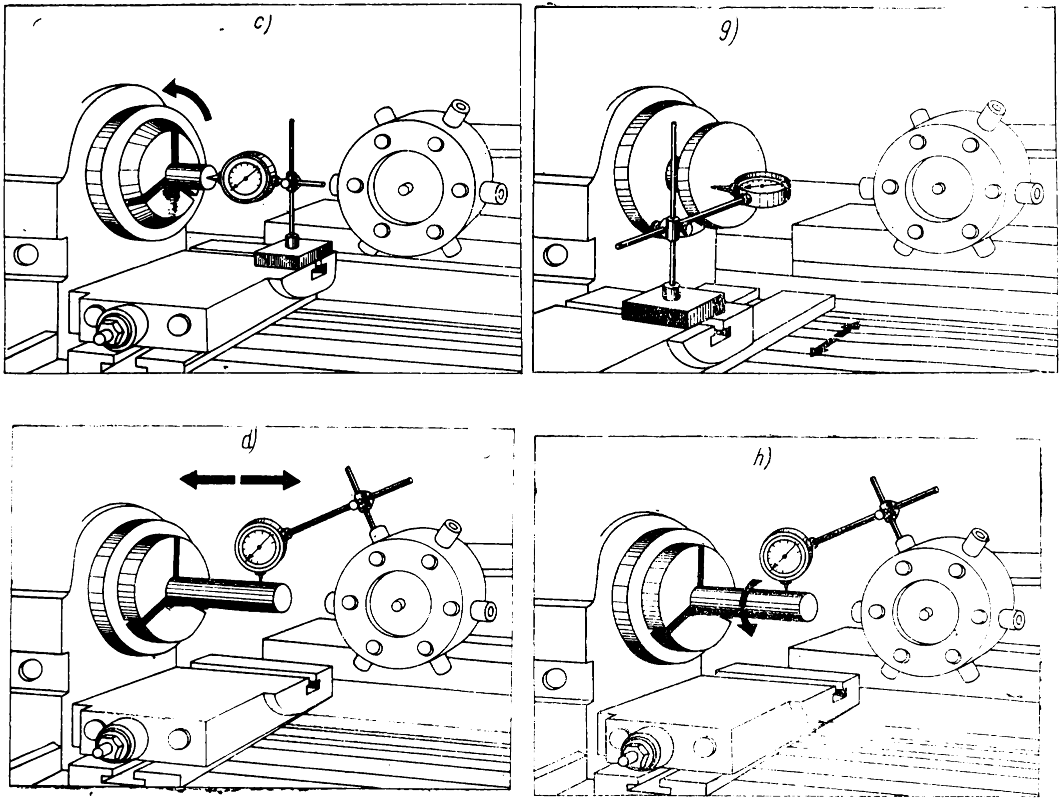
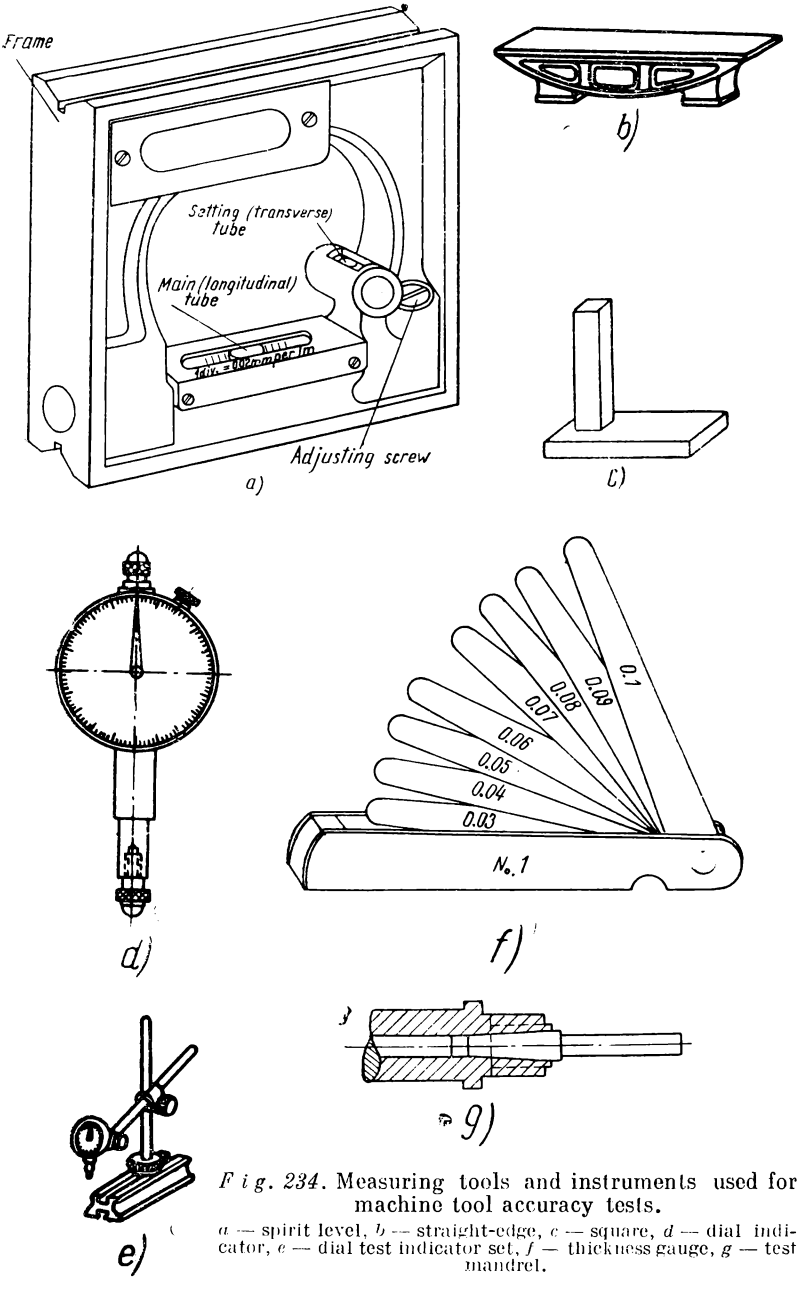


Fig. 233. **Accuracy tests of an automatic screw machine.**

a — radial runout of the front seating surface for the collet closing sleeve (tolerance 0.01 mm), *b* — radial runout of the taper bore of the collet closing sleeve (tolerance 0.015 mm), *c* — axial runout (slip) of the spindle (tolerance 0.01 mm), *d* — spindle axis is parallel with travel of the turret slide in a vertical plane (tolerance 0.01 mm over full travel of turret slide), *e* — axis of turret tool hole in the working position is parallel with turret slide travel (tolerance 0.01 mm over full travel of turret slide), *f* — alignment of the turret tool hole in the working position with the axis of spindle rotation (axes coincide) (tolerance 0.02-0.03 mm), *g* — cross slide travel square with spindle axis (tolerance 0.1 mm on length of cross slide travel), *h* — radial runout of mandrel clamped in the chuck collet (tolerance 0.04 mm for mandrel diameter from 6 to 10 mm, 0.06 mm for mandrel diameter from 10 to 18 mm, and 0.08 mm for mandrel diameter from 18 to 80 mm.



F i g. 234. Measuring tools and instruments used for machine tool accuracy tests.

a — spirit level, *b* — straight-edge, *c* — square, *d* — dial indicator, *e* — dial test indicator set, *f* — thickness gauge, *g* — test mandrel.

Flatness may also be tested with marking compound and a surface plate. A thin layer of marking compound is applied on the surface plate which is then rubbed back and forth with a slight motion on the surface of the way being tested. Flatness is characterised by the number of bearing spots per unit area which remain on the way surface.

The results of accuracy tests are to determine the actual errors in manufacture and in relative positions of the principal units and parts.

The following measuring tools are employed in accuracy tests: spirit levels, straight-edges, squares, dial test indicator sets, thickness gauges, and test mandrels (Fig. 234).

Of the above-mentioned, only dial indicators, spirit levels, and thickness gauges require explanations of their principle of operation and design.

A dial indicator is a sensitive instrument having a dial with 100 divisions. Each millimetre of motion of the contact point will turn the hand a full revolution on the dial. Therefore, a hand movement of one division corresponds to a contact point movement of 0.01 mm. The spindle and contact point are returned by spring action. The dial may be rotated by a knurled ring, after the contact point touches the surface to be tested, so that the "0" graduation coincides with the hand.

Spirit levels are based on the movement of an air bubble in a curved glass tube of fluid. In the horizontal position of the level, the bulb is in the centre; any inclination of the level will displace the bubble from its central position. As a rule, one scale division corresponds to an inclination of 0.04 mm per metre.

Thickness gauges consist of a set of steel blades of varying thickness from 0.04 mm and up.

The parallelism, squareness, alignment, and true running of parts and units of machine tools are also tested (see Fig. 233 *a*, *b*, *c*, and *f*).

Parallelism (Fig. 233 *d* and *e*) is checked by attaching or applying a dial test indicator set on one tested surface so that the contact point touches the other surface. The dial indicator is moved together with the first surface or along it. The parallelism of slide or saddle ways with the spindle is checked in this manner.

Alignment of the axes of two components is checked as illustrated in Fig. 233 *f*; squareness is checked as in Fig. 233 *g*.

Rotating parts of machines, and first of all the spindle, are checked for true running, i. e., for runout in the radial and axial directions (Fig. 233 *a* and *c*).

The permissible errors in machine tool accuracy tests are established by the standards.

Performance tests and determination of the rate of production are the most important of the tests because they indicate how the machine actually operates under load and its production capacity.

Performance tests are conducted at higher speeds and feeds than those employed in regular operation.

As a rule, the machine is loaded 25 per cent in excess of its rated load.

Frequently automatics and semi-automatics are furnished completely tooled for a definite workpiece and may be tested at the specified rate of production. This test will show how the machine operates and what accuracy and surface finish may be obtained on the work it produces. Automatic and semi-automatic lathes are tested on a run of several hours, and sometimes several shifts, to determine the production capacity over longer periods of time.

Automatics and semi-automatics, furnished without tooling (poor practice), should be tested on the production of suitable work.

Automatic and semi-automatic lathes, in accordance with their type and construction, are designed for producing work of the third and fourth grades of accuracy. Certain models of single-spindle automatics may, however, produce work of the second grade. The surface finish obtained may vary from $\nabla 3$ to $\nabla 7$ (according to U.S.S.R. Std. GOST 2789-51).

The machining errors are usually within the ranges given in Table 3. Much more accurate work may be obtained if the machine and tools are more carefully set up and adjusted.

Specially accurate work is done on high-accuracy machine tools and automatics which are usually called *precision-type*. These automatics are manufactured to tolerances two or three times narrower than for ordinary models.

When testing machines which have been in operation for a period of time, it will be necessary to determine how the wear of the parts affects workpiece accuracy. For example, wear of the ways may be the cause of toolslide travel not parallel with the spindle axis. This will distort the form of the turned surface. Out-of-roundness on the spindle journals may cause out-of-roundness on the work machined.

Machine tool accuracy tests should be conducted periodically and all required repairs and readjustments should be made without delay.

It must be remembered that errors in the form and size of workpieces are due, not only to errors in the machine tool, but also to incorrectly located and clamped work, errors in the attachments, and tool settings.

Power consumption tests show whether the drive motors have been selected properly. They enable the efficiency of the drive to be determined, as well as the quality of its design and manufacture.

The power consumption at medium and at high speeds and feeds is determined in the tests.

The approximate efficiency of the drive in the setup for a definite workpiece may be determined on the basis of the measured power N consumed when the given workpiece is being machined and the idling power N_i measured at the same spindle and camshaft speeds.

The efficiency (usually denoted by the Greek letter Eta — η) is computed from the formula

$$\eta=\frac{N-N_i}{N}.$$

Power consumption tests are conducted with comparatively simple measuring instruments: two wattmeters which register the power and a tachometer or a revolution counter and a stop watch for determining the spindle speed.

Laboratory tests, conducted on machine tools, aim at improvements in their quality. They include all production (acceptance) tests and, in addition, tests for rigidity, vibration resistance, power distribution, and wear resistance, as well as tests which check the operation of various mechanisms, units, and systems.

Rigidity tests are often conducted in the acceptance of a machine tool and consist in determining the capacity of various units for resisting loads that may appear. Machining accuracy depends on the rigidity of the spindle, toolslides, and the machine as a whole. On the other hand, the rigidity values indicate, in some measure, the quality of manufacture and assembly of the machines and may reveal methods for increasing the rigidity.

Practically, rigidity tests consist in applying a force to the tested unit (Fig. 235) and measuring its deflection. The rigidity value R is defined as the force F in kilogrammes divided by the deflection a in millimetres:

$$R=\frac{F}{a}\ \text{kg/mm}.$$

The larger this ratio, the higher the rigidity of the unit, or, as they say, the less it will "give".

Vibration-resistance tests. Vibration developed in the operation of machine tools has a detrimental effect on the surface finish and accuracy of the work produced. It increases wear in the machine parts, sharply reduces tool life, and, in general, decreases the rate of production. Under unfavourable circumstances, vibration may even be the cause of a break-down.

There are many causes of vibration. In the first place, they are associated with unbalanced rapidly rotating parts, with alternating or variable rigidity, with cutting speeds and feeds, with the condition and geometry of the cutting tool, and with the properties of the material being machined.

Vibration-resistance tests are conducted to develop methods of eliminating vibration. The tests are made during operation, for the most part, and consist in registering the surface finish quality of definite test samples and the absence of chatter-marks (due to vibration).

Such instruments as the *vibrograph* or the *oscillograph* are employed for more accurate vibration-resistance research. They measure the frequency and amplitude of vibrations of the operative units.

The following practical measures are often applied to increase the vibration resistance: *elimination of excess clearance in the spindle bearings and toolslide ways, increasing the rigidity of fixed joints, more careful alignment and balancing of rapidly rotating parts (including the blank), changing the tool angles, and the application of high-speed cutting methods.*

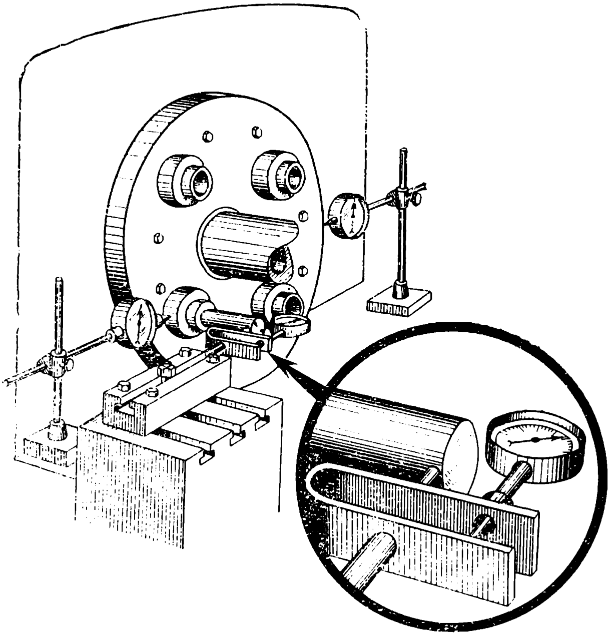


Fig. 235. Arrangement for conducting rigidity tests on machine units.

§ 137. TESTING AUTOMATIC TRANSFER MACHINES

Tests are conducted to check the reliability of the various systems of machine tools, units, transfer devices, and other mechanisms in the fully automatic production of work of the specified quality and at the required rate. Each machine tool in the fransfer machine is subjected to all the tests of § 136. The component units may be installed in the transfer machine only after they have all been tested and their manufacture and assembly have been found to be of the required quality. The transfer machine as a whole is then tested to check the cycle time value.

CHAPTER III

METHODS OF INCREASING THE PRODUCTIVITY OF LABOUR

§ 138. MULTIPLE MACHINE TOOL HANDLING

Multiple machine tool handling or operation is such work of machine tool operators when a single operator, by tending and other service, provides for the simultaneous operation of several machine tools. This is one of the most important methods known for increasing labour productivity. Automation is the most effective means for extending multiple machine tool handling. The operation of automatic and semi-automatic lathes offers the most favourable conditions for extensive multiple machine tool handling since their required handling is comparatively small.

Multiple machine tool handling increases the quantity of workpieces produced per unit of time by each operator and substantially reduces production costs.

The following measures must be carried out to ensure that in multiple machine tool handling each automatic or semi-automatic will produce the maximum number of pieces and will not stand idle:

1) time required for handling operations and idle motions should be reduced to a minimum on all machine tools handled;

2) machining time required on any one machine tool should enable all the handling operations to be performed on the other machine tools, i. e., it should cover the sum of the handling times on the other machines, handled by the operator, in addition to the time required for going from one machine to another;

3) the machine tools must be selected for simultaneous handling so that the ratio of machining and handling times allows several machines to be handled at the same time;

4) the machine tools selected must be conveniently arranged in a compact group;

5) measures must be taken to facilitate the handling, loading, unloading, and transfer of workpieces;

6) chips should be regularly disposed of;

7) tool readjustment and resetting must be made without delays;

8) all machines must be regularly furnished with all the bar stock, blanks, tools, and auxiliary materials that they may need.

Multiple automatic lathe handling requires that the setup man should periodically readjust and reset the automatics and continuously maintain them in proper working condition to eliminate downtime. Besides the setup man, the group of automatics is usually serviced by an operator who restocks the automatics, transfers the finished workpieces to the next machine, and removes the chips. On semi-automatic lathes, the operator performs handling and control operations as well. Consequently, multiple machine tool handling can be effective only if the time required for the handling operations performed by the operator on all the machine tools, is less than the machining time on each of the handled machines.

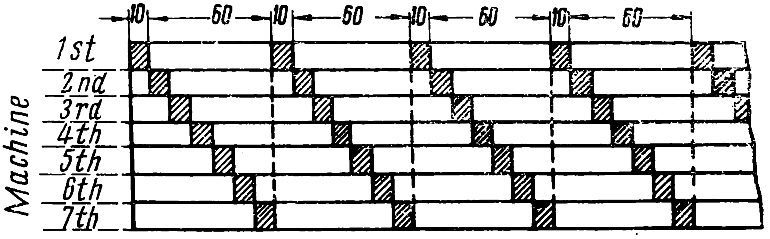


Fig. 236. Multiple machine tool handling chart.

For example, a setup man or operator handles several machine tools of the same type operating with a cycle time T_c. The attention of the operator for a time of T_s minutes (including time required for going from machine to machine) is required for one machine tool after a cycles. Then the servicing periodicity for each machine tool will be aT_c minutes and the number of machine tools handled by a single operator (or setup man) may be determined from the following equation:

$$m \leqslant 1 + \frac{aT_c}{T_s} \text{ machine tools.}$$

The same equation shows that multiple machine tool handling is feasible if:

$$T_s \leqslant aT_c.$$

The number of simultaneously handled machines may be checked graphically (Fig. 236).

If the setup man or operator services machine tools which require his attention after equal periods of time, the feasibility of multiple handling may be determined from the same formulas. In this case, a will be the minimum number of cycles after which attention is required for the machine with the largest servicing time T_s.

Transfer machine servicing is always a case of multiple machine tool handling and is performed by a small number of persons. This number is based on full provision for the specified rate of production.

§ 139. WORKPLACE ARRANGEMENT AND WORKDAY ROUTINE

The workplace includes the machine or machines handled by a single operator or setup man, the floor space occupied by the machine or machines with their stores of blanks or work-in-process, with all handling and transfer devices and auxiliary equipment. The workplace of a setup man must be furnished with a cabinet (Fig. 237) in which all fixtures and attachments, cutting, measuring, and mechanic's tools, and all drawings and documents, concerning the job on hand, are stored in exemplary order. Detail drawings, job slips, and inspection tools and instruments may be arranged on the table top of the cabinet. The workplace of an automatic lathe operator is illustrated in Fig. 238.

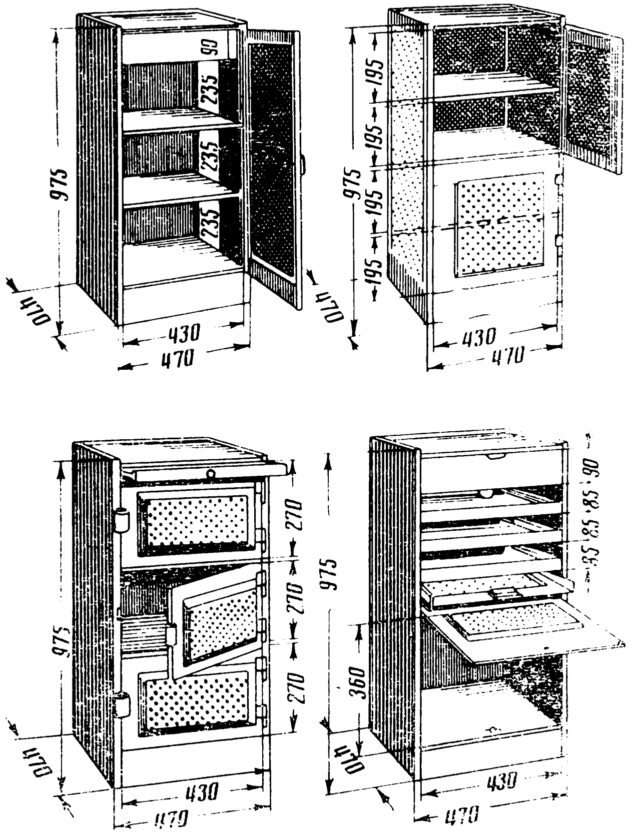


Fig. 237. Cabinets for tools, attachments, and fixtures.

If industrial management is properly developed in the plant, the setup man's workplace will also be furnished with a display board showing the daily output of workpieces and the per cent of plan fulfilment for the shift. Such display boards are very useful as they enable each employee to follow his production achievements.

The workday routine of the setup man and operator greatly affects systematic operation of machine tool equipment and may be a means of increasing labour productivity. Machine tools may be employed to their full capacity only if they are handled with care, periodically lubricated, cleaned regularly and, what is most important, operated with due attention.

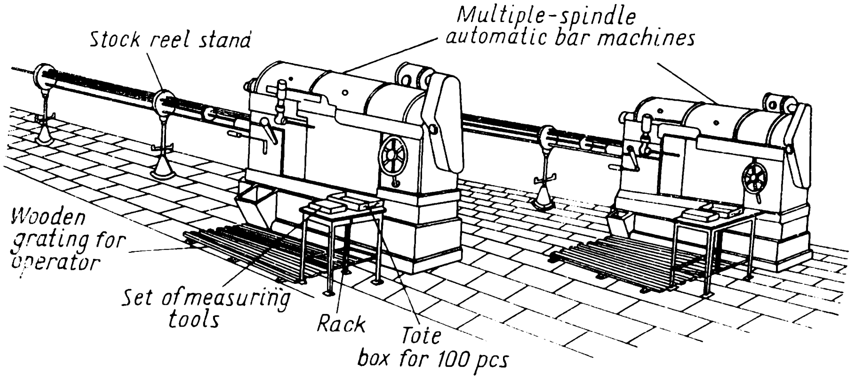

Stock reel stand
Multiple-spindle automatic bar machines
Wooden grating for operator
Set of measuring tools
Rack
Tote box for 100 pcs

Fig. 238. Workplace for automatic bar machines.

In most cases, automatics operate in two or even three shifts. Therefore, each machine should be taken over, before the shift, from the operator of the previous shift or given over, at the end of the shift, to the next operator in perfect running order.

The setup man, and the operator as well, should report for work 15 or 20 minutes before the shift starts. They should watch the operation of the machine to make sure it is in order or they should inquire about stoppages in the previous shift. Before starting work, it is necessary to check whether all machine tools are furnished with a sufficient store of blanks or stock and whether they have spare sets of cutting tools. The job slips for new work must be looked over, all required attachments, cams, and change gears must be received, and preparations must be made to start work without delay. All preparatory work must be done in such a manner that no necessity will arise to leave the machine tool during the first half of the shift.

Just before lunch time, the setup man must report to the foreman concerning all measures that must be taken to ensure uninterrupted operation in the second half of the shift.

The workday routine must be planned so that the machine tools are always under someone's care and so that the setup man can make periodic rounds of all the machine tools, remedying all troubles that may arise and demonstrating proper working methods to the operators.

The setup man is a responsible person, entrusted with a large number of machine tools, cutting tools, attachments, and fixtures. He should teach the operators by demonstrating effective working methods and contending with down time and spoilage and thus raise their skill.

All the operators, supervised by a first-class setup man, fulfil and overfulfil their job tasks. They keep their machine tools in excellent condition and become more skilled day by day.

The famous Soviet lathe hand, G. S. Bortkevich, in describing his working methods, wrote: "I was able to reduce the time required for loading and unloading work to a considerable extent by improving the arrangement of my workplace. Persistent training in these and other handling movements is the reason why I work easily, without "spurts", and why I am not especially tired after operating my lathe all through the shift without a break".

§ 140. PROGRESSIVE PROCEDURE IN SETTING UP AND OPERATION

As a result of extensive study of his job, machine tool or group of machines, each operator and setup man must employ all technical means to increase the rate of production and to produce work of higher quality. In the Soviet Union, each worker strives to help his section, department, and plant to achieve a maximum output of excellent-quality items with minimum labour input per piece.

There are many approaches to this matter.

Many lathe hands have achieved high-production operation by increasing the cutting speed; others, in addition to high cutting speeds, use heavy feeds, up to 2 or 3 mm per revolution. Progressive lathe hands increase the rate of production by reducing the cycle time. They pay special attention to excellent execution of each production operation.

Progressive lathe hands continuously devise new means for increasing production and improving the quality. They make time- and labour-saving suggestions concerning improvements of the manufacturing process, increasing cutting speeds and feeds and modernising the machine tools and attachments to reduce machining and idle time.

Besides this, they improve the quality of the work they produce to a considerable extent and handle their machine tools with special care.

Much work has been carried out in the post-war years to raise the economic indices of machine tool utilisation and to increase the savings in materials, electric power, cutting tools, etc.

The following measures will help the setup man to increase the production capacity of his section:

1. Bar stock should be sorted into the required size and stored at the automatic bar machine where it is employed. When about $^2/_3$ of the bar is used up a new bar is prepared for restocking. Restocking is associated with time losses from 0.6 to 1 minute for small bars and from 1.5 to 2 minutes for heavy bars. These losses can be considerably reduced by removing the burrs on the bar beforehand and by watching carefully for the moment when a bar is completely used up. An automatic rod magazine will further reduce the time for restocking.

2. Reduce the time required to load and unload the workpiece in semi-automatic lathes.

This can be accomplished by employing rapid-action chucks (pneumatic or hydraulic types) and by performing manual operations faster.

3. Do all tool resetting in minimum time. For this purpose, use interchangeable tools and holders which may be precisely set before installing them on the machine.

Considerable time is still being lost in changing and adjusting various tools on automatic and semi-automatic lathes. For example, the average time required for resetting various cutting tools will be: form tool—2 to 4 min, straight turning tool—1 to 2 min, boring tool—2 to 3 min, cut-off tool—2 to 3 min, reamer—2 to 3 min, twist drill—0.5 to 1 min, threading die—2 to 4 min, and a tap—2 to 5 min. These times may be considerably reduced if the tool crib service is improved.

4. Quickly remedy all minor troubles in the machines, attachments, and cutting tools to sharply reduce all machining time losses.

5. Automatic and semi-automatic lathes are frequently changed over to other jobs. This change-over is always associated with considerable setup time losses. Six-spindle automatics require from 4 to 5 hours of setup time and single-spindle models require from 2 to 4 hours.

The approximate times required for the various elements, in changing over to a new job, are as follows:

Setting spindle speeds	1 to 3 min
Setting feeds	1 to 3 min
Changing the collet and stock pusher .	2 to 4 min
Adjusting stock feeding and chucking .	3 to 6 min
Installing new cams	60 to 120 min
Adjusting the cams	20 min

The time losses in change-overs may be reduced by examining the production task for the following week or month and planning the jobs for each machine tool so as to reduce the number of elements which must be changed.

A number of Soviet machine tool plants now manufacture automatic and semi-automatic lathes which do not require that new cams be made or even changed in changing over to a new job. On these machines, the principal elements can be set up (or changed over) in 40 to 60 minutes.

6. Progressive production workers manage to reduce time losses due to poor production management. In Soviet plants measures are taken to completely eliminate working time losses associated with waiting for the job assignment, detail drawing, and blanks, with obtaining tools and attachments, with receiving the required instructions and with between-shifts losses.

7. Progressive setup men plan each day's work to increase machine tool utilisation. This includes drawing up a schedule of servicing, planning the receiving of blanks and turning over finished work, putting the work places into proper order, drawing up a plan for resetting and readjustments so as to reduce downtime, preparing all tools required for resetting, and planning other work (studying the detail drawing, inspecting and testing the machines, etc.) which are a part of his duties.

8. In addition to increasing the rate of production, progressive operators and setup men improve the quality of the workpieces being produced. This is done by very careful setting up and resetting and by checking the setup periodically (checking the size, form and surface finish of the work). To maintain a high quality, it is necessary to see that all cutting tools are properly sharpened and set, that the blank is reliably clamped, that measuring devices are properly selected and carefully adjusted, and that the required cutting fluid is applied and in the proper amount.

9. Progressive workers increase the period of trouble-free operation of machine tools. This results in more intensive and better machine tool utilisation. To prevent breakdowns and to avoid general overhauls, the setup man keeps the machine tools under careful observation, he observes all prescribed rules for their maintenance, sees that the machines are properly lubricated and cleaned and he also remedies all troubles during operation without delay.

10. Setup men should study new working methods devised by progressive operators; they should help the process engineers in making stop-watch time studies of the separate elements and then teach other operators these methods.

Operations which should be studied in the first place include:

automatic lathes: restocking, adjusting the chuck clamping force, adjusting stock feed, setting and adjusting cutting tools, setting up the automatic, lubricating and cleaning the machine, remedying minor troubles, and checking the workpiece;

semi-automatic lathes: loading, aligning, clamping, and unloading the workpiece, setting up and adjusting the semi-automatic, lubricating and cleaning the machine, checking the workpiece, and remedying minor troubles.

Those operations should be studied first that require the most time, reduce the rate of production and also those which are not correctly performed by certain operators since the time and labour they require are excessive.

§ 141. RATE SETTING

Rate setting, which serves to determine the standard time required to machine one workpiece and the rate of production in unit time, is a powerful means of increasing the productivity of labour.

The standard time for machining one piece is expressed in seconds or minutes per piece. The rate of production is expressed as the number of pieces made per hour or per shift.

The standard time for making one workpiece or for performing certain operations on a given machine tool is the minimum time required under existing production conditions. It should be based on the most expedient cutting conditions, the use of good quality cutting tools, and on furnishing the workplace with all required items for the work to be done without any delay. No extra time may be added to the standard time to compensate for production management disorders. The standard time (time per piece) T_p in seconds is determined by the formula:

$$T_p = (t_m + t_h + t_s + t_d + t_f) \text{ sec.}$$

In which: t_m is the machining time in seconds during which one workpiece is machined;

t_h is the handling time in seconds during which all handling operations are performed, such as loading, clamping, and unloading the workpiece, advancing and retracting the tools;

t_s is the servicing time or time required for setting, adjustments, changing tools, etc., in relation to one piece;

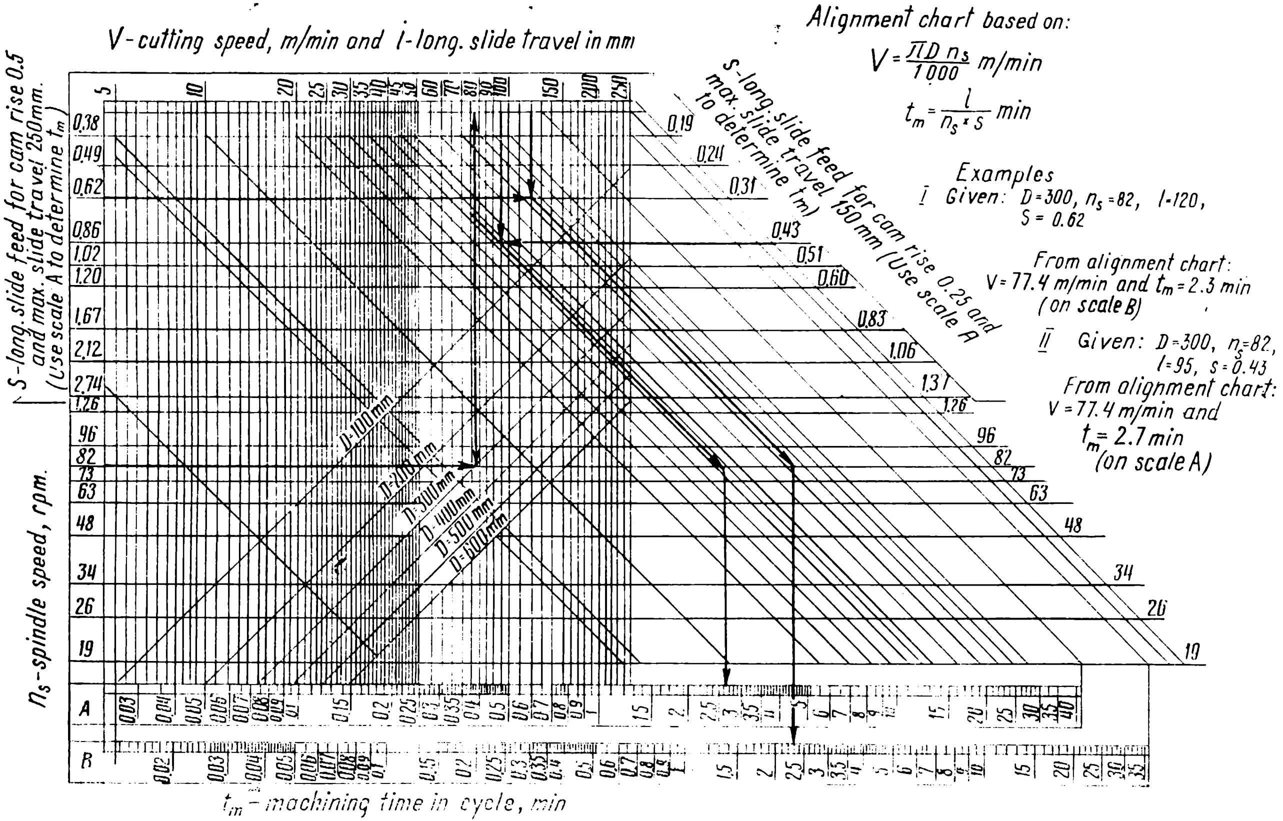
t_d is the time in seconds required for various organisational measures and delays including lubrication and cleaning the machine in relation to one piece;

t_f is the fatigue time required for rest and personal needs in relation to one piece.

The machining time t_m may be determined from the alignment chart in Fig. 239.

The standard output Q_o is determined as the reciprocal of the time per piece expressed in minutes:

$$Q_o = \frac{60}{T_p} \text{ pcs/min or } Q_o' = \frac{3{,}600}{T_p} \text{ pcs/hr.}$$



Alignment chart based on:

$$V = \frac{\pi D n_s}{1000} \text{ m/min}$$

$$t_m = \frac{l}{n_s \times S} \text{ min}$$

Examples

I Given: $D = 300$, $n_s = 82$, $l = 120$, $S = 0.62$

From alignment chart: $V = 77.4$ m/min and $t_m = 2.3$ min (on scale B)

II Given: $D = 300$, $n_s = 82$, $l = 95$, $s = 0.43$

From alignment chart: $V = 77.4$ m/min and $t_m = 2.7$ min (on scale A)

Fig. 239. Alignment chart for determining the machining time.

The gross rate of production of a machine tool is expressed as

$$Q_g = \frac{60}{T_c} \text{ pcs/min}$$

or

$$Q'_g = \frac{3,600}{T_c} \text{ pcs/hr}$$

in which T_c (cycle time) is equal to $t_m + t_h$.

The actual rate of production will equal:

$$Q_a = \frac{60}{T_c} \eta \text{ pcs/min}$$

or

$$Q'_a = \frac{3,600}{T_c} \eta \text{ pcs/hr}$$

in which η is the utilisation factor.

The actual rate of production should equal the standard output. Therefore the utilisation factor accounts for the servicing and delay time, time required for minor current repairs and also the time for personal needs of the operator.

In machining simple work, factor η is taken equal to 0.95; for very complex work produced on multiple-spindle machines, it is taken as 0.8. To calculate the gross and actual production of semi-automatic lathes, it will be necessary to add the time for loading and unloading the work (if this time is not overlapped) to the cycle time T_c.

Rate setting also concerns the piece-rate (P) in kopeks for making one piece:

$$P = WT_p \text{ kopeks}$$

in which T_p is the time per piece in minutes;

W is the wage-rate per minute of an operator of the given skill rating.

The essential point of the wage system is to evaluate working time in monetary units in accordance with the skill required for the job, the intensity of the work, and the physical effort required.

In determining the production cost (in cost calculations), the setup time must also be taken into consideration. The setup time (t_{su}) in seconds is the time required for setting up the machine for a lot of n workpieces and for preparing the machine for operation. Cost determinations are based on the calculated time T_{cal} which is defined as:

$$T_{cal} = T_p + \frac{t_{su}}{n} = \left(t_m + t_h + t_s + t_d + t_f + \frac{t_{su}}{n}\right) \text{ sec.}$$

All improvements in the manufacturing process and developments in the skill and technical knowledge of the plant personnel will raise the productivity of labour. Therefore, the time standards must be decreased and the output rate increased.

CHAPTER IV

MACHINE TOOL MAINTENANCE, REPAIRS, AND MODERNISATION

§ 142. MAINTENANCE

Very careful maintenance is required to keep machine tools in proper running condition.

Experience has shown that the periods of trouble-free operation of a machine tool can be substantially prolonged with proper maintenance.

Maintenance of machine equipment is divided into three stages: servicing before starting work, during operation, and after finishing work.

Servicing before starting work. Before starting to work, each operator or setup man must inquire of his opposite number in the previous shift about all troubles and defects that were discovered. After making sure that the troubles are completely eliminated, he must inspect the machine. He should check whether controls operate without failure and whether the clamping devices operate reliably. He should also thoroughly lubricate the machine.

If the machine has been standing idle for a prolonged period, it should be started and run idle for 10 or 15 minutes. It is advisable that the operator or setup man does all this work before the beginning of the shift to avoid losses in production.

After the machine is switched on for automatic operation and the first few workpieces are made they should be carefully measured to check whether they conform to the specifications of the detail drawing. Cutting tools must always be reliably clamped.

Servicing during operation includes careful observation to see that all mechanisms operate faultlessly, that the temperature of plain bearings does not exceed 60° C and that of antifriction bearings does not exceed 75°, that all engagements and disengagements take place without impacts, and also that there is no jamming, excess clearances, or misalignment of the various units.

In addition to this, the devices for feeding lubricant should be periodically checked, as well as the effectiveness of the oil filters. Cutting fluid should never get into the lubricating system or on the electrical devices and motors; there must be no leaks in the system and the cutting fluid must be delivered directly to the zones where metal is cut.

Machine tools must be serviced during operation so that the guards and shields are not removed and so that they operate normally.

Servicing after finishing work consists in switching off the machine, cleaning it of any remaining chips, retracting all operative units to their initial positions, wiping off the machine with a clean rag, and preparing it for trouble-free operation in the next shift.

At the end of the shift, the workpiece being machined must be finished and, for multiple-spindle machines, all the workpieces must be finished or the machine should be stopped in a position where not one workpiece will be spoiled.

Systematic and attentive maintenance of machine equipment will sharply increase its production capacity and utilisation, and reduce the amount of repairs required and the cost of operating the equipment.

If the necessity of adjustments or minor repairs to certain mechanisms arises during servicing, such work should be done without delay, not waiting until the defect leads to serious trouble in the machine.

143. REPAIRS

Repairs are made to maintain machine equipment in a condition to operate effectively over a long period.

The system of repairs preferred in the Soviet Union is called planned or preventative maintenance. This system includes all facilities for preserving equipment, such as current (on-duty) servicing between repairs, planned periodic inspection and cleaning, periodic accuracy tests, planned minor and medium repairs, and planned general overhauls. The system consists in conducting various preventative measures and maintains the equipment in an excellent operating condition all the time.

Automatic and semi-automatic lathes, as a rule, are installed in plants in which precise schedules are established for periodic inspections, checks, minor and medium repairs, and general overhauls.

In minor repairs, only a part of the units is disassembled (in accordance with the results of periodic inspection), worm parts are replaced or renovated, taper jibs and other sliding surfaces are smoothed down or scraped, and the lubricating, coolant, hydraulic, and other systems are adjusted.

Parts subject to replacement in medium repairs or general overhauls are revealed by minor repairs.

All units are disassembled for medium repairs. The subsequent stages are the same as for minor repairs.

A general overhaul consists of complete disassembly, washing of all parts and units, replacement of all defective parts, and a careful restoration of all worn parts.

The construction of the machine tool should be quite clear to the repairmen before starting a general overhaul as should be the order in which the repairs and subsequent reassembly are to be done.

In disassembly, all parts should be numbered and the order of their reassembly should be established and set down. A general overhaul should fully restore the initial accuracy and production capacity of the machine tool.

In the course of the overhaul, mating parts are measured. This reveals wear and defects and serves to draw up the defect schedule which, subsequently, is the basis for making repairs.

The processing methods employed in repair operations must ensure high quality and the reguired accuracy.

Worn ways of beds, cross members, slides, and saddles are usually rapaired by scraping and, less frequently, by grinding. The repaired surfaces are checked by surface plates, straight-edges, and the mating parts. For example, if bed ways are scraped, they are checked finally with the saddle using a marking compound. A thin layer of marking compound is applied on the ways of either the bed or saddle which is then moved along the bed. There should then be a uniform dustribution of bearing marks on the ways. If there are "bald" spots, without bearing marks whatsoever, or places with a continuous coat, the ways have been unsatisfactorily scraped and more metal must be scraped off where there is much marking compound. This operation is repeated until the bearing marks are distributed uniformly in spots over the full length and width of the ways.

It is often necessary to repair spindle journals and their bearings in general overhauls. If a plain bearing is used, the spindle journals are subject to wear and lose their initial form. In such cases, it will be necessary to regrind the journals, removing the minimum possible amount of metal. This is especially important if the spindle is casehardened and the hardened layer is thin.

Worn antifriction bearings should be replaced with new bearings.

Plain bearings are repaired by scraping and are also checked with marking compound.

It is best to replace excessively worn gears with new gears.

The following are some of the up-to-date repair methods employed to restore and reinforce worn or broken parts: arc or gas welding (including the welding of cast iron parts), surfacing of worn places on parts, flow welding, electric or gas metal spraying to build up worn places, and building up little-worn vital surfaces by chromium plating. Certain parts, not subject to high heat or loads, may be glued together with carbinol glue (for metals).

Other methods are lapping-in, heat treatment, and shot peening which are used for finishing working surfaces, surface hardening, and increasing the fatigue strength.

Assembly operations, applied in equipment repair, should be planned to avoid expensive fitting work wherever possible.

§ 144. MODERNISATION

Modernisation is defined as the alteration of units and parts or the addition of new units or parts to machine tools, already in service, with the aim of increasing the rate of production and the accuracy, extending the possibilities for multiple machine tool handling, and lightening the operator's labour.

The following types of modernisation are most frequently applied: increasing the ranges of cutting speeds and feeds, and the available power, increasing the number of pieces machined simultaneously or the number of cutting tools, decreasing idle time, and increasing the degree of automaticity.

It will be necessary to make strength calculations of the machine to establish the upper limits of feasible increases in cutting speed and available power, and to reveal the links in the kinematic chains that limit further increases. These calculations should check the drive elements in respect to the torque and power that may be transmitted, as well as their strength, rigidity, vibration resistance, wear resistance, etc.

The available power may be increased by replacing the drive motor with a more powerful one, at the same time, increasing the width or number of drive belts and the module of the gears. As a rule, the factor of safety allows the motor power to be increased by 25 or 30 per cent in comparison with the rated value without any major design alterations.

Electric motors are designed to permit temporary overloads up to 50 per cent for 8 or 10 minutes and 25 per cent for 30 minutes. Therefore, if the length of the cycle is considerably less than these values and the machine operates under varying conditions, the periodic (peak) load may somewhat exceed the rated power of the motor.

Before increasing the available cutting speeds, it will be necessary to check the rigidity and vibration resistance of the machine and to operate with minimum overhang of the tools.

Vibrations may be reduced by a better finish and more accuracy of all jointing surfaces, by providing interference in all fixed associations, by using cardboard or rubber washers in such joints, by decreasing the number of joints, and by increasing the rigidity. This latter may be provided by more reliable and effective fastening of the parts.

In semi-automatic lathes, modernisation often concerns work clamping facilities which should operate with minimum time losses. This entails the use of pneumatic, hydraulic, or electric devices which sharply reduce operator fatigue and increase production.

The automation or mechanisation of work clamping facilities will enable multiple machine tool handling to be extended with less physical effort required from the operator.

Modernisation in automatics and semi-automatics is often aimed at reducing time required for setting up and adjustments. Rapid action setting-up mechanisms and devices are applied in such cases. They facilitate and speed up tool setting and adjustments to the required work size.

At the present time, automatic work gauging devices are seldom used for automatic and semi-automatic lathes. This auxiliary operation requires a great deal of time and, therefore, the application of gauging devices, that relieve the operator of frequent measurements and the resulting necessary stoppages, are very desirable.

It is often expedient to provide supplementary gauging, loading, and signalling devices to simplify handling operations if machines are to be operated with multiple machine tool handling or at high cutting speeds.